ELEPHANT WOODY VEGETATION INTERACTION AND HUMAN-ELEPHANTS CONFLICTS CONTROL IN MWEA NATIONAL RESERVE

BY

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a degree in any other university. No part of this thesis may be reproduced without the prior written permission of the author and/or University of Eldoret.

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DEDICATION

In loving memory of my Grand Father (Mr. Makau Ilia) who rested at an old age of 107 years in 2010 and inspired me to appreciate Nature. To my iconic and loving Mamma, Philomena Muthio.

ABSTRACT

Elephants respond to management actions like fencing and indirect disturbance, causing detrimental effects due to spatio-temporal variability in the intensity of habitat use. Reduced dispersal area of the fenced-isolated 42 km^2 Mwea National Reserve and a growing density of 2 elephants km^{-2} may impede the savanna ecosystems' equilibrium between elephant and tree densities. This study, aimed at determining the elephant habitat preference, their impacts on woody species and effectiveness of electric fence in control of Human Elephant Conflicts (HECs). A randomized block design was used to select 40 belt transects distributed proportionately in the four main vegetation types for sampling of woody species utilization parameters and elephant dung pile count. Evaluation of the fence effectiveness and locals' opinions towards the reserve was by review of HECs records and interviews. Fixed Kernel buffers on dung density inferred a high preference for habitats within proximities of Tana and Thiba rivers. Mean dung densities showed that elephants preferred bushland, woodlands and grassland in descending order respectively ($F_{(3,\ 36)}$ $=7.36$, $p<0.001$). *Acacia ataxacantha, A. brevispica* and *A. tortilis*, were the elephants' most preferred woody species and their mean heights correlated negatively with elephant dung densities. Elephants utilized their preferred woody species in significantly different modes ($G_{(18,\ N=756)}$ $=178.23$, $p<0.000$) depending on the woodiness of the tree. The main stems of *A. tortilis* were broken off (61%) and debarked (20%), the other shrub species were browsed selectively (90%). It was evident that elephants severely affected their preferred woody species by impeding their height, damaging exploitation and surpassed utilization threshold of 50% per species. The opinions of residents from the fenced and unfenced sides on the electric fence effectiveness in control of HECs differed significantly ($\chi^2_{(1,\ N=90)}$ $=29.11$, $p<0.0001$). On average, they rated the fence as 76% effective. The fence effectively deterred the elephants but there was positively correlated ($R^2=0.25$) HECs in the open edges against elephant population over 5 years. This was due to the 'funneling' effect of the linear fence design that pushed elephants to the open riversides. The long-term sustainability of the elephant forage and reserve-community relationship is henceforth at risk and worse even when the propensity of the impact's magnitude increases exponentially with the elephant population growth over time. I recommend that the reserve's carrying capacity for elephants be determined to obviate the negative impacts associated to high elephant population density.

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LIST OF ACRONYMS

ANOVA- Analysis of Variance

CITES – Convention on international trade of endangered species

GIS- Geographical Information System

GPS- Global Positioning System

HECs- Human Elephant Conflicts

HWC- Human Wildlife Conflicts

IUCN'S- International Union for Conservation of Nature

KWS- Kenya Wildlife Service

MNR- Mwea National Reserve

OB- Occurrence Book

PR- Preferential Ratio

SD- Standard Deviation

SE- Standard Error

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

African elephants *Loxodonta africana* (Blaumenbach, 1797) populations declined significantly in the twentieth century, in Kenya specifically, it was drasticaly reduced from 167,000 in 1973 to 20,000 individuals in 1989 due to massive poaching for ivory (Moses Litoroh, Omondi, Kock, & Amin, 2012). In 2010 the Kenyan population was estimated to be circa 35,000 growing at an average rate of 4.5% p.a. (M. Litoroh, Ihwagi, Mayienda, Bernard, & Douglas-Hamilton, 2010), concurrently, human population increased to 39.5 million Kenyans in 2011 at a rate of 2.4% p.a (Kilele, 2012). Much of the former elephant range has been encroached upon by farmlands leaving discontinued fragments of habitats with significant challenge of sustainable biodiversity conservation and escalating Human-Elephant Conflicts (HECs) (Moses Litoroh, Omondi, Kock, & Amin, 2012).

Mwea National Reserve (MNR) covering 42 km^2 was gazzeted in 1975 as one of the government's strategies to ensure elephant numbers build-up again in many areas of the country (Chira, 2003). In 1998, MNR was fenced off under a joint venture between KWS and the European Union. This was done by erecting a 16 km electric fence to mitigate the then escalated HECs which included high crop raid rates and death of four people between 1990 and 1996 (Chira, 2005). Fencing was conducted after translocation of a family group of 23 individual elephants to Tsavo East National Park in 1996 leaving about 27 elephants (Chira, 2002). The aim was to reduce the elephant density in the reserve and create space and time for the habitat to recover (Chira, 2003). This reserve therefore, has management challenges for sustainable conservation of habitat and viable wildlife diversity due to its small size and the isolated nature.

The elephant population in MNR has increased since the enclosure in 1998 from 55 individuals to approximately 90 individuals in 2012 (Ngene, Kimutai, Mukeka, & Omondi, 2012). This indicates a population growth rate of 4.5% p.a. in 14 years translating to estimated elephants density of 2 km^{-2}. Elephants have been described as keystone species capable of altering vegetation structure and dynamics within their ecosystem (Western, 1989). At high and more localized densities, elephants negatively impact on vegetation structure and biodiversity, reduce woodlands, converting them to more open grassland thus affecting ecosystem's integrity and functions (Ruggiero, 1993; Tchamba, 1995). High elephant densities and more uneven distribution have more lasting impacts on woody plants than on grass or herbs (Laws, 1970).

Elephants show preferential utilization of woody species that may change the woody species and vegetation structural composition if elephant density increases unchecked (Chira & Kinyamario, 2009). Further, high elephant density has the capacity of hampering the self-regulating resilience that exists between elephant density and tree density in savanna ecosystems (Mapaure & Campbell, 2002). Therefore, change in tree mean height and elephant utilization mean heights of preferred woody species can be used to estimate the impacts of elephant utilization on the species' resilience over time.

The opinions of communities faced with the challenges related to resource use competition between people and wildlife, land uses and socio– economic activities that affect their livelihoods need to be established and incorporated in sustainble conservation of the environment (M. M. Okello, Buthmann, Mapinu, & Kahi, 2010; Sarkar, 1999). Therefore, in evaluating the effectiveness of the MNR electric fence in mitigating HECs, it was prudent to compare and contrast the perceptions of communities living along the fenced and unfenced edges of the reserve.

1.2 Problem Statement

Elephants respond to management actions like fencing, water provision, and indirect disturbance effects that may have detrimental effects by causing spatio-temporal variability in the intensity of use by elephants. Reduction of dispersal area by fencing the isolated 42 km^2 MNR with density of 2 elephants km^{-2} and subsequent increase in elephant population may alter the equilibrium that exists between elephant and tree densities in savanna ecosystems. Many elephant conservation areas under similar threats have been identified in Kenya including the MNR, the coastal forests of Shimba hills and Arabuko-Sokoke. A mean elephant density of 1.6 km^{-2} in Shimba hills National Reserve was observed to have considerable negative impact on the vegetation (Höft & Höft, 1995). Evaluation of the current MNR elephant population distribution and effects on the woody vegetation against the reserve's capacity was therefore, necessary.

The thick undergrowth of MNR vegetation structure that reduces visibility to less than 10 m undermines the effectiveness of direct observation techniques. This difficult necessitates the need for comparative study using innovative indirect methods to infer elephant spatial and temporal distribution as well as, habitat and woody species utilization preference. In such cases, use of indirect method in study of elephants-habitat dynamics has advantages over direct observation methods. For instance, elephant dung count can account for retrospective elephant distribution pattern depending on the dung decay rate in the ecosystem, something which can only be achieved by direct observation of elephants over a long period of time, which is time consuming and expensive. Inference on elephant dung decay rates can relate to seasonal habitat utilization, which can in turn be correlated to the level of elephant damage in a given area or habitat. Use of elephant dung pile count and elephant browse marks on woody plants as indirect evidence of elephant activities and impacts on vegetation in MNR were therefore, adopted for this study.

It is now over 14 years since KWS intervened to resolve the then escalated HECs in MNR by translocating elephants and constructing an electric fence. A number of factors including fence design, voltage, maintenance, elephant pressure and behaviour may influence the success of electric fences in managing crop-raiding by elephants (Garai & Carr, 2001; Hoare, 2003; C. R. Thouless & Sakwa, 1995). Hence, the need to evaluate the electric fence effectiveness in control of HECs by reviewing the fence and HEC records and establishing the local community's perceptions towards the reserve as indicators of sustainable conservation.

1.3 Justification

Considering the high installation and maintenance cost of electric fencing, there is a need for more research to establish the factors that determine the effectiveness of electric fences in management of elephant populations and resolving escalated HECs in and around conservation areas. This justifies the main objective of this study, which will act as an evaluation of the results of the major management measures taken twelve years ago at MNR. In the case of very small isolated habitat areas like MNR, there comes a point when the question must be asked: is there – or should there be – a future for this elephant population (Moses et al., 2012)? By evaluating the current elephants populations interaction with woody plants, I will endeavor to answer this question by projecting the future trend. In addition, this study will find out how such conservation measures impact on the local community perceptions and livelihoods as indicators of sustainable conservation.

1.4 Conceptual Framework

The basis of this study can be conceptualized in a framework based on the four historical management events that have taken place because of the external and internal factors acting on the isolated reserve. The fourth event will be the evaluation set to be done by this study: to evaluate the interaction effects of elephants and woody vegetation and the fence effectiveness in curbing HWCs as indicators of sustainable conservation.

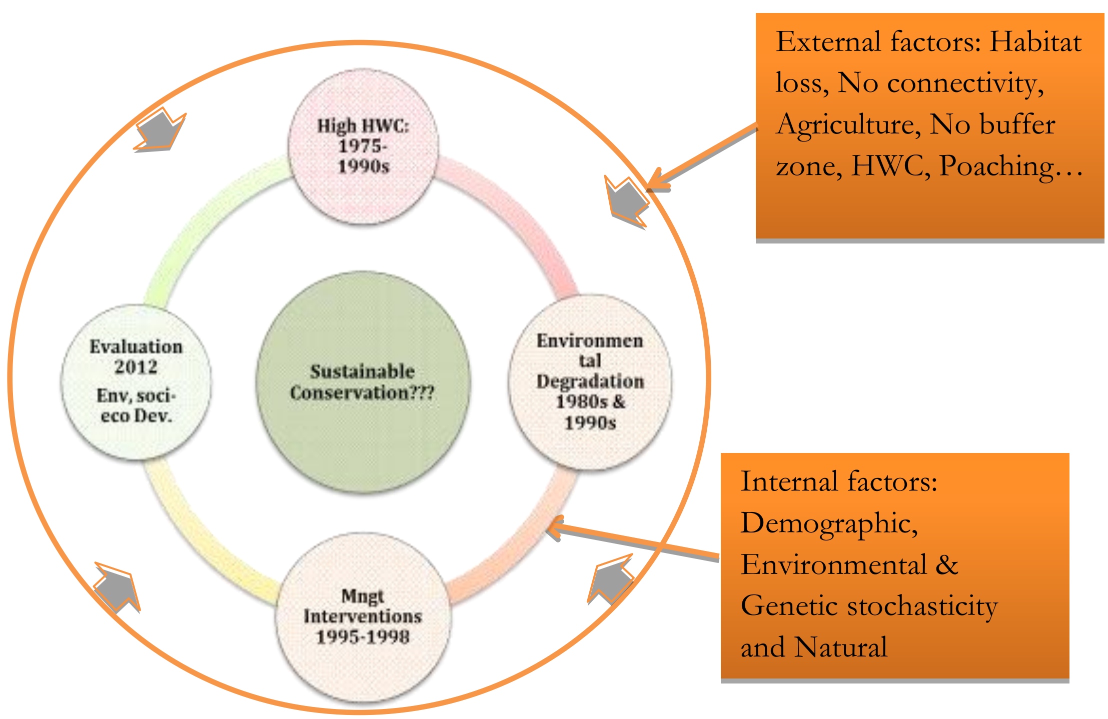

Figure 1: A scheme relating the Enclosed MNR management events to sustainable conservation (source: Author, 2012)

Sustainable conservation is said to be realized when environment conservation is integrated with socio-economic development of the community. The establishment of MNR in 1975 created Wildlife Island surrounded by human settlement. This formed a human wildlife conflict hotspot especially on the Makima settlement. These conflicts were escalated by the fact that the reserve is a small area of 42 km^2 with high elephant densities with no barriers at the boundaries. This creation of small isolated closed island with no migration corridors had far much reaching impacts on the environment, such as habitat degradation, habitat fragmentation, and local extinctions of some wildlife species, land conversion and loss of biodiversity.

These factors called for intensive management strategies to mitigate the escalated Human Wildlife Conflict and environmental degradation within the ecosystem. The management strategies taken were: to translocate nearly half of the elephant population to Tsavo; Erection of 16 km electric fence; Settlement of the displaced local people in the Makima settlement scheme; Reintroduction of some of the locally extinct species and the development of a comprehensive and strategic management plans for the Reserve.

It's now been over 12 years since these interventions were undertaken hence, the need to appraise the achievements of these measures in addressing the environmental, social and economic issues experienced in and around the reserve there before. The findings of this study will determine whether sustainable conservation is been realized or what other recommendations needs to be done to achieve this.

1.5 Objectives

The main objectives were to determine elephant's habitat preference and their impacts on woody vegetation and to assess the reserve's electric fence effectiveness in control of human elephant conflicts.

Specific objectives

1. To determine elephant habitat preference in MNR using dung count method.
2. To determine the preferred woody plants by elephants in MNR.
3. To evaluate the reserve's electric fence effectiveness in control of HECs.

1.6 Research Questions

1. What habitat do elephants in MNR prefer?

   Sub questions;

   i) What is the elephant distribution pattern in MNR?

   ii) Which habitat has the highest elephant dung density?

   iii) What is the elephant dung decay rate in MNR?

   iv) How are the dung decay categories distributed in the four habitats?

2. Which plants do elephants in MNR prefer?

   Sub questions;

   i) Which woody plant species do the elephants in MNR prefer?

   ii) What is the distribution for the preferred woody species in the four habitats?

   iii) How are the number of utilized preferred plants related to the dung count per transect?

   iv) What is the plant and elephant utilization mean height of the preferred woody species?

   v) What height class do the elephants utilize most?

   vi) What is the association between the dung count and the mean height of the preferred species per transect?

vii) What are the main elephant damage types on the preferred woody species in MNR?

3. a. How effective, has MNR electric fence been in control of HECs?

Sub- questions

i) What is the fence design and maintenance challenges of the MNR electric fence?

ii) Are there reported cases of elephant fence breakage since the inception of the electric fence?

iii) Are there any reinforcements made on the fence to improve its effectiveness in reducing fence breakage by elephants?

iv) Comparing the fenced and unfenced sides, which one has more recorded HECs in the occurrence book?

v) Is there any relationship between the elephant population and the number of reported HEC incidents per year?

vi) According to the local residents from the fenced and unfenced sides of the reserve, has the fence been effective in control of HECs?

3. b. What are the opinions of the local residents around MNR on the conservation of elephants in the reserve and related HECs?

Sub- questions

i) Comparing the periods before and after fencing of the reserve, which one has the highest level of HECs?

ii) What are the losses that arise from the HECs?

iii) Between the response from the fenced and unfenced sides of the reserve, which one has more HECs?

iv) How do the elephants escape the reserve into the farmland?

v) What methods do the residents use to deter the elephants from invading their farms?

vi) In what other ways does the MNR management help in control of HECs?

vii) What other animals cause conflicts on both sides?

viii) What benefits do the residents gain from the reserve?

ix) What are the expectations and opinions of the local residents on MNR?

CHAPTER TWO

LITERATURE REVIEW

2.1. Elephant population trends and their conservation challenges

Loxodonta africana (Blaumenbach, 1797) *africana* specifically, refers to the savanna elephant, the largest of all elephants (CITES, 2008). It is the largest land animal, with males standing 3.2 metres (10 ft.) to 4 metres (13 ft.) at the shoulder and weighing 3,500 kilograms up to a reported 12,000 kilograms (CITES, 2008). The female is smaller, standing about 3 metres (9.8 ft.) at the shoulder. Most often, savanna elephants prefer open grasslands, marshes, and lakeshores. They range over much of the savanna zone south of the Sahara (CITES, 2008).

African elephants' populations declined significantly in the twentieth century largely as a result of poaching (Douglas-Hamilton, 1987). Ivory trade was banned in 1989 and consequently, most major populations in eastern and southern Africa are now stable or have been steadily increasing since the mid-1990s at an average rate of 4.5% per year (Blanc et al., 2007). Kenya's elephant population was drasticaly reduced from 167,000 in 1973 to 20,000 individuals in 1989 because of massive poaching for ivory (Douglas-Hamilton, 1987). In 2010 the Kenyan population was estimated at around 35,000 and increasing (M. Litoroh et al., 2010) attributed this to the ivory trade ban and increased anti-poaching efforts by KWS. Along with the steady increase in Elephants' population their return to parts of their former ranges where they had not been seen for nearly 30 years, the human population in Kenya has also grown drastically to 39.5 million over this period at a rate of 2.4% p.a (Kilele, 2012). For that reason, the challenge of conserving many small fragmented and isolated elephants in Kenya today is quite different to what it was 20-30 years ago (Moses Litoroh et al., 2012).

Small and fragmented populations are of concern because the probability of extinction increases exponentially with decreasing population size or with decrease in area occupied by a population (Burkey, 1989; Hanski, 1999). Populations are more likely to survive in contiguous tracts than when isolated (Burkey, 1989). Fragmentation may however, improve the survival of a protected sub-population when a population is heavily persecuted (Shaffer, 1987). Isolated populations are at risk of inbreeding depression and even in larger populations there can be a gradual loss of genetic variability (Franklin, 1980). With decreasing population size the magnitude of the effects on population dynamics, demographic, environmental and genetic stochasticities and natural catastrophes may increase (Shaffer, 1987). In small populations (10s to 100s) demographic stochasticity can result in a population decline and lead to extinction (Shaffer, 1987). Environmental stochasticity also affects population size and in a variable environment any loss in population size proportionaly increases the chances of population extinction (Shaffer, 1987).

Movement between fragmented population is important for species that need large areas like elephants (Siegfried, Benn, & Gelderblom, 1998). However, there are significant difficulties in establishing wildlife corridors for elephants (Johnsingh & Williams, 1999). Where elephants occur in small parks their numbers can soon exceed desired levels. To manage elephants population, size should be well known. If populations are declining research focused on determining why the population is declining should be implemented and increased protection or decreased utilization, or alternatively introduction of more animals to boost the population (Siegfried et al., 1998). If populations are increasing; culling, contraception, or translocation may be needed (Siegfried et al., 1998).

2.2. MNR vegetation types

The main vegetation types in MNR are:

(i) Bushland,

(ii) Woodlands (*Acacia mellifera* and *Commiphora africana* woodlands),

(iii) Wooded grassland.

Vegetation map, Figure 2 below (Chira, 2002) shows the location of the various vegetation types which have poorly defined boundaries between the various vegetation types.

a) Bushland and woodlands habitats

These main vegetation types are dominated or co-dominated by either *Acacia mellifera*, *Commiphora africana*, *Grewia bicolor*, *G. villosa,* and *A. ataxacantha* woody species (Chira, 2003). The woody species composition difference among the three vegetation type: *A. mellifera* woodland, *C. africana* woodland, and the bushland from the wooded grasslands can be explained mainly by differences in the edaphic factors (Chira, 2003). For instance, the areas covered by wooded grasslands have black cotton, gray sandy and reddish soils, while the areas covered by woodlands and the bushland have reddish to gray sandy soils (Bear, 1952). The population structure of woody plants in the reserve is mainly composed of woody plants below 3 m in height forming a thick understory which reduces visibility to less than 10 m thus inhibiting direct wildlife census techiniques (Chira, 2002).

a) Wooded Grassland

This vegetation class is dominated by *Combretum sp, Terminalia brownii* and *C. africana* among other woody species. This habitat has the most distinctive woody species composition from other vegetation types making it the most diverse in species composition probably owing to edaphic factors (Chira, 2003). Wooded Grassland in MNR is one major vegetation type that is under serious threat (Chira, 2002). This vegetation type has a high proportion of woody plants recruitment mainly invading from the woodlands of the reserve. Similarly, there are also incidences of invasive herbaceous species that have also dominated the wooded grasslands (Chira, 2002). The invasion by both the woody and herbaceous species has lowered the quality and quantity of food resources of the wooded grasslands (Chira, 2002). The invasive species trends have not been arrested due to lack of a fire management plan for more than 20 years according to reserve's records. Some areas that were accidentally burned in the reserve show emergence of grass species that are stimulated by fires and are of high quality to grazers. With the current re-introductions of some herbivores, there is a need to maintain the quality of the reserve's wooded grasslands (Chira, 2005).

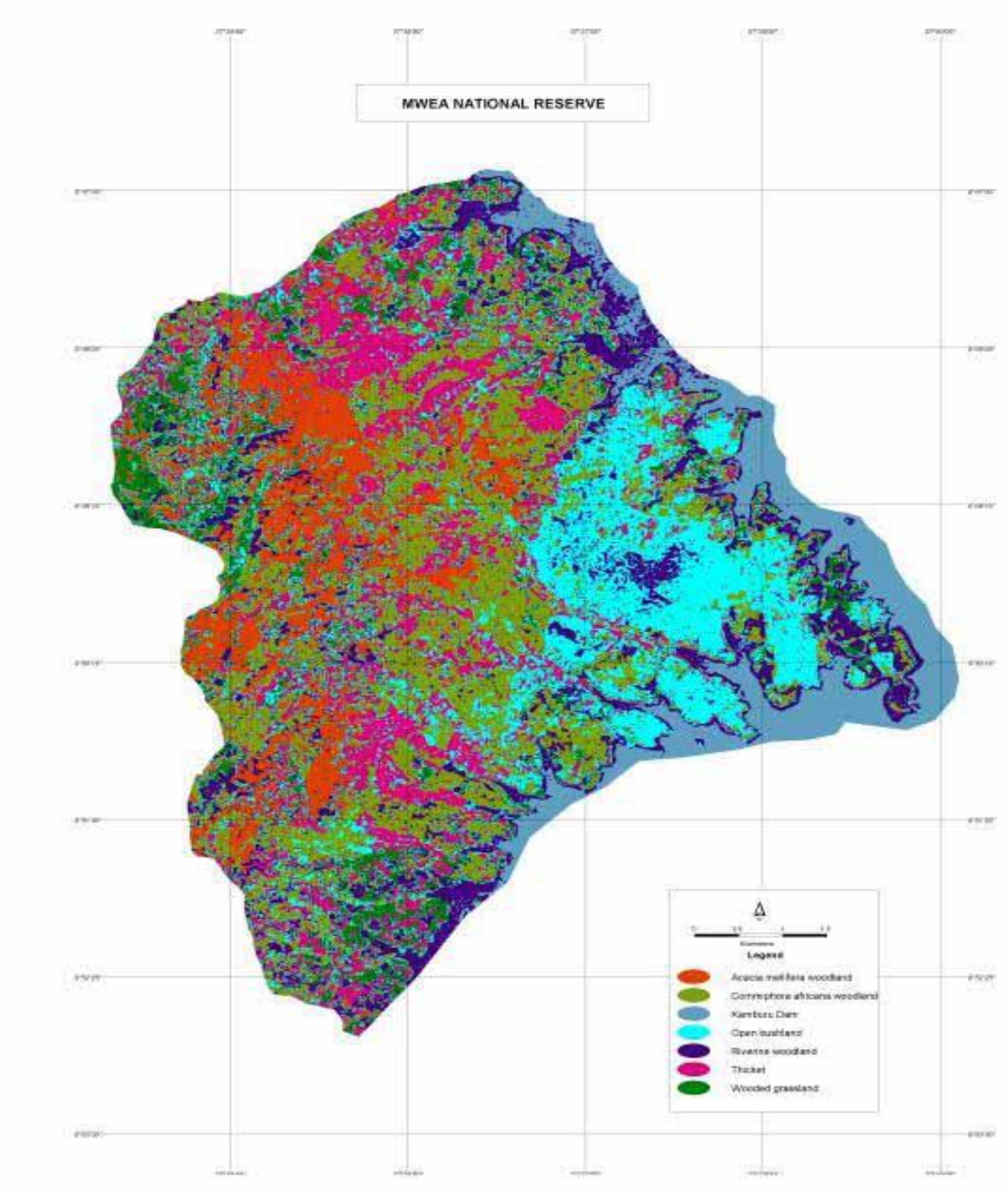

Figure 2: MNR Vegetation Map (Source: Chira, 2002)

2.3. Elephants distribution and effects on woody vegetatation

2.3.1. Elephant local distribution in a conservation area

Environmental factors affect elephant population dynamics, home range, migration patterns, diet, group size, and composition; all of which can vary tremendously, in turn influencing the dynamics of elephants and their habitats (Kadzo Kangwana, 1996). African savanna elephant's diet may include grass, herbs, bark, fruit and tree foliage. In savanna habitats, grass may make up 70% of the elephants' diet in the wet season with larger proportions of browse contributing to their diet as the dry season progresses. Estimates for mean daily intake range from 4% to 7% of body weight (Laws, 1970), with lactating females consuming proportionately higher quantities (Laws, Parker, & Johnstone, 1970).

Water availability and distribution are the most important factors affecting or limiting elephant local movement (Laws, 1970; Poche, 1974; Weir, 1972), with elephants tending to aggregate in close proximity of the main rivers (Stokke & Du Toit, 2002). Not only the availability of surface water, but also the context of the water source is important for elephants: rivers, floodplains, the ecotones and sodic sites associated with these provide nutritional and habitat benefits that are not always found in the vicinity of artificial waterholes (Stokke & Du Toit, 2002). On the other hand, bulls are more evenly distributed with regard to surface water sources than mixed groups, probably due to differences in the nutritional requirements, avoidance of aggression and the increased mobility of bull groups compared to mixed herds (Stokke & Du Toit, 2002). Since areas around larger rivers have unique functional, structural and compositional characteristics, they should receive specific attention in impact monitoring programs and elephant management policies (Smit & Ferreira, 2010).

The elephant distribution and habitat selection coincide with seasonal climatic changes and the corresponding changes in food and water availability (Viljoen, 1989). The seasonal variability use of habitat is probably an important mechanism of survival and optimum utilization of resources, while at the same time reducing the impact on dry season habitat (Viljoen, 1989). Elephants' also respond to management actions like fencing, water provision, and indirect disturbance effects of culling and translocation prompting conservationists and scientists to argue that these may have detrimental effects by standardizing elephant impact across space and time (Loarie et al., 2009; Owen-Smith et al., 2006; Smit & Ferreira, 2010; Van Aarde & Jackson, 2007; Van Aarde et al., 2006). In areas where traumatizing operations such as culling, use of thunder flashes, mass capture and translocation occurs, an indirect disturbance effect makes elephants disperse into calmer areas of their home range (Smit & Ferreira, 2010).

Several survey techniques provide information that forms the basis of population estimates for African elephants (Douglas-Hamilton, 1996). Visibility in MNR is reduced to less than 10 m by the thick undergrowth in most of the habitats, thus, presenting a challenge of direct visual wildlife census techniques (Chira, 2002). For elephants that live in dense woodlands and forests, scientists often use dung surveys (Barnes, 2001). Population estimates based on dung counts require estimates of the number of dung piles per km^2, the number of piles produced by an elephant in a day and the rate at which dung piles decay (Barnes & Jensen, 1987). Seventeen studies across Africa have estimated elephant average defecation rate to be 25.3 ±8.5 boli/day (Olivier, Ferreira, & van Aarde, 2009). However, sampling intensity and observer bias can influence estimates of dung pile density (Jachmann & Bell, 1984). In addition, limited visibility in woodlands makes it difficult to observe elephants defecating to estimate defecation rates (Barnes, 2001).

Comparison of studies on elephant dung decay rates in different sites in Africa have yielded to a decay range of between 43–167 days (Olivier et al., 2009). Habitat types and boli sizes affect decay rates, with the presumed lower detectability and faster decay rate of small boli contributing to the possibility of skewed age frequencies (Olivier et al., 2009). However, the decay rates of small and large boli are usually similar (Olivier et al., 2009). Dung decay rates can also be highly variable between sites (Hedges & Tyson, 2002), and simple extrapolations of dung decay between sites and seasons is made difficult by differences in rainfall regime and elephant diet (especially the fruit content of the diet) and probably vegetation (Barnes, 2001).

2.3.2. Effects of Elephant-woody vegetation interaction

Elephants are keystone species with the ability to alter vegetation structure and dynamics within their ecosystem (Western, 1989). In more localized high densities, elephants impact on vegetation structure and biodiversity reducing woodlands and converting them to more open grassland hence affecting other mammalian species (Ruggiero, 1993; Tchamba, 1995). In some cases the reduction of woody vegetation has been beneficial in opening up tse tse fly infested woodlands and transforming bushland to grassland for grazers (Western, 1989). Often, fire or logging may initiate change with elephants playing a maintaining role in a given ecosystem (Dublin, Sinclair, & McGalde, 1990).

Chira and Kinyamario, (2009) found elephants in MNR to preferentially utilize woody species by mainly foraging on *Acacia ataxacantha* and *Grewia bicolor* out of the five preferred woody species and avoiding the coppices of many other woody species notably *Commiphora africana*, *Acacia tortilis*, *Acacia mellifera*, *Combretum aculeatum*, which characteristically dominated the reserve’s canopy. Elephants capitalize on the strong coppicing ability of damaged plants, thereby maintaining the selected tree species at optimal height for browsing, while allowing non-selected species to grow to canopy height (Jachmann & Bell, 1984). Structural properties of the vegetation hence appear to be less important for the elephants' choice of habitat, instead, the floristic composition and the presence of certain fodder plants direct the main habitat choice of elephants (Höft & Höft, 1995).

Elephants either: push over or uproot tree, break the main stems or side branches, and selectively browse on the crowns of shrubs or strip off the bark of trees (Birkett & Stevens-Wood, 2005). Direct effects of debarking on the vitality of trees are rarely observed; however, excessive debarking is followed by fungal infections, in many cases resulting in successive crown-dieback and premature death (Höft & Höft, 1995). Foraging on mature woody species by elephant before fruiting may also affect their regeneration (Chira & Kinyamario, 2009). Extended dry seasons or prolonged droughts can compromise tree viability (Wahungu et al., 2011) and amplify negative elephant effects (van Wyk & Fairall, 1969).

2.4. Human Elephant Conflicts (HECs)

Human–elephant conflicts are the negative interactions between humans and elephants (Omondi, Bitok, & Kagiri, 2004). Some of the negative effects of elephants on humans include crop-raiding, deaths and injuries to humans, and to livestock (Tchamba, 1995). On the other hand, elephants are killed and their range severely altered by human activities (Haigh, Parker, Parkinson, & Archer, 1979; Kadzo Kangwana, 1996). HEC is widespread in most elephant range areas (Blanc, Thouless, A., Dublin, & Barnes, 2003) and has intensified where elephants and humans are in close contact (Naughton, Rose, & Treves, 1999). It is particularly a major concern where former elephant range has been encroached upon by farmlands (Osborn & Parker, 2002).

Human–elephant conflict is increasingly jeopardizing elephant conservation as many elephants are killed by wildlife authorities in attempts to reduce conflicts (Omondi et al., 2004). Elephants are also killed illegally by local people in response to destruction of their crops and deaths and injuries to their livestock (Omondi et al., 2004). In Kenya, for example, 130 elephants were killed in HECs situations between 1990 and 1993 whereas elephants killed 108 people during the same period (Kiiru, 1995). In the Tsavo-Amboseli area in Kenya, 15 people were killed and 24 injured by elephants between 1993 and 2004 (Kioko, Okello, & Muruthi, 2006). In the same area during the same period, 44 elephants were killed (Kioko et al., 2006).

2.5. Use of Electric Fence in Management of HECs

In Kenya, more than 1200 km of electric fencing has been installed to protect farmlands from elephants and an additional 1300 km of fencing was planned (Omondi et al., 2004). While electric fences are considered effective in reducing crop-raiding (Hoare, 2003), literature on the use of electric fencing to manage crop-raiding by elephants suggest that a number of factors including fence design, voltage, maintenance, elephant pressure, and behaviour may influence their success (Garai & Carr, 2001; Hoare, 2003; C. R. Thouless &

Sakwa, 1995). Considering the high installation and maintenance cost of electric fencing, there is a need for more research to establish the factors that affect the effectiveness of electric fences in deterring elephant crop-raids in different settings (M. D. Graham et al., 2009).

Elephants respond to management actions like fencing and water provision which prompts the argument of the detrimental effects this response may cause by homogenizing elephant impact across space and time (Loarie et al., 2009; Owen-Smith et al., 2006; Van Aarde & Jackson, 2007; Van Aarde et al., 2006). Sufficient and reliable prior information is therefore, necessary to justify both the considerable expense of constructing a fence and the commitment to sustainable maintenance that any fence requires (Hoare, 2003). Enormously expensive fencing projects have failed completely against elephants by disregarding the simple observation that elephants encountering a fence will often walk along it until they reach the end hence, exacerbating problems for people who live near the end (Smith & Kasiki, 1999). An encircling fence layout is best since it avoids 'funneling' elephants around the open ends of a linear fence (Hoare, 2003).

Elephants in Kenya are not confined to national parks and reserves (Western, Russell, & Cuthill, 2009). Furthermore, most of the wildlife uses land adjacent to or completely outside protected areas in most parts of the year (M. M. Okello & Kiringe, 2004). Many rural farmers living within elephant ranges are beyond the reach of the conventional approach used to mitigate HECs thus take the responsibility of defending their own farms from elephants (M. D. Graham & Ochieng, 2008) using traditional farm-based elephant deterrent systems (Osborn & Parker, 2003). There is some evidence to show that improving these traditional deterrent systems through the introduction and application of simple and affordable tools can reduce levels of crop raiding (Sitati & Walpole, 2006). Such traditional farm-based elephant deterrent systems include chili rope fences and cow bells, metal cowbells; Metal cowbells hung from each chili fence to act as an alarm if an elephant tried to break through the perimeter rope fence. Chili smoke briquettes, chili dung lumps; made by mixing chilies with elephant dung and a little water in a mound and leaving to dry in the sun. These briquettes generate a noxious and deterring chili smoke when burnt over night. Additional deterrents include use of noisemakers such as ‘banger sticks’ made from local materials and matchstick heads. watchtowers and solar powered torches (M. D. Graham & Ochieng, 2008; Sitati & Walpole, 2006) and the use of African honeybees (*Apis mellifera scutellata*) (Lucy, Anna Lawrence, Douglas-Hamilton, & Vollrath., 2009). Other deterrent methods that have been tried and tested are: digging of ditches and moats along the periphery of the target resource, the creation of buffer zones, and buffer crops, which are relatively unpalatable to elephants e.g. tea, timber, tobacco or sisal (Hoare, 2003).

2.6. Perceptions of Communities Living Adjacent to Wildlife Conservation Areas

Recent studies have indicated that the majority of the local people around protected areas have negative feelings about state policies and conservation programmes (Okech, 2010). Land-use change from traditionally communal land to exclusive use of wildlife and tourism have a direct impact upon the local communities and prompts them to raise questions about the wildlife policy. Human- wildlife conflicts are a consequence of the problem of resource utilization in conservation areas. Such conflicts adversely affect biodiversity conservation efforts. Wildlife harm people and property, which results to retaliatory killing of wildlife in 82% of the protected areas in Kenya (Okech, 2010). MNR is one of the protected areas susceptible to more than 70% of the identified threat factors such as: lack of dispersal areas, conservation areas that cannot effectively and sustainably support viable tourism industry, and wildlife populations without active management intervention (Okech, 2010). The rise in human-wildlife conflict could evolve into a major crisis if a solution is not immediately found (Ogodo, 2003).

In a scenario where wildlife-induced damages to human property and life are neither controlled nor compensated, negative local attitudes towards conservation and wildlife resources become entrenched (M. M. Okello & Wishitemi, 2006). Agriculturists lose crops to various wildlife species (Naughton-Treves, 1998), and although elephant damage is infrequent compared to other pests, it is often the most severe (Naughton-Treves, 1998; Tchamba, 1995) or comes just before harvest when effort and resources have already been invested (Gadd, 2005). Elephants are also dreaded crop-raiders because they are difficult to chase away and may kill people (De Boer, Ntumi, Correia, & Mafuca, 2000; Tchamba, 1995; C. Thouless, 1994). To farmers, the cost of elephant damage is not only the direct loss of a source of nutrition and income, but also indirect losses of education for children who have to stay home to guard the crops (Naughton-Treves, 1998) or alter their schedules to avoid elephants, and psychological stress from anticipating nocturnal raiders (Gadd, 2005). To conservationists, the cost of elephant damage is also tremendous. Hostility towards nearby national parks arises when people feel they have not been adequately compensated for damage (Naughton-Treves, 1998). People may take matters into their own hands, eliminating unwelcome animals (Nyhus, Tilson, & Sumianto, 2000). In fact, the single most common reason for disliking game reserves is the invasion of crop-raiding animals (De Boer et al., 2000). Conflicts with wildlife can threaten the survival of animals and erode support for conservation areas (Gadd, 2005). This is made worse when local communities do not benefit from wildlife resources and are alienated from wildlife-related economic enterprises such as the lucrative tourism industry. A negative perception exists in many local communities where ‘people versus animals scenerio’ is expressed by conservation authorities (Okech, 2010). When local communities feel that both governments and conservation stakeholders value wildlife more than their lives, livelihoods or their aspirations; retaliation and opposition to conservation initiatives can be swift and uncompromising (Okech, 2010).

Involving local communities in sustainable natural resource use and conservation must be encouraged. No rural-based education about the use of such resources can succeed if local community needs and opinions are not met and incorporated in conservation practice and policies (Sarkar, 1999). Effective human wildlife conflicts mitigation along with enhanced security will require dedicated efforts from all key stakeholders: KWS, relevant government departments, private landholders, communities, county councils, local, and international partners (Moses Litoroh et al., 2012).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

Mwea National Reserve: *"An undiscovered oasis of tranquility"* (www.kws.org)

3.1.1. Location

The MNR is located within Makima Location (Figure 3), Karaba Division of Mbeere District, in Eastern Province, a distance of about 200 km from Nairobi. Geographically, MNR is between latitudes 0°45'N and 0°52'N, longitudes 37°35'E and 37°40'E and at an altitude of between 950 and 1150 m above sealevel (Chira & Kinyamario, 2009).

3.1.2. Legal status

The reserve was gazetted through legal notice No. 2 on 29th January, 1976, and it covered an area of 68 km^2 under the jusrisdiction and management of the then larger Embu county council in 1975. It is the only conservation area in the county. Wildlife and peasant farmers with their livestock occupied the reserve before its gazettment and were later displaced in 1975 and allocated 10 acre plots outside the 68 km^2 of the reserve: Makima settlement (Chebures, 1989). In 1978, part of the reserve was annexed during land adjudication and the entire location leaving the current area that the reserve occupies: 42 km^2. This change of land tenure and use has since created a rift between interests of the community and wildlife conservationists (Chira, 2003).

3.1.3. Landscape

The Mwea savanna ecosystem comprises of small hills with bushy vegetation and scattered large trees. Other areas are wooded grasslands while along the main rivers, large trees with thick undergrowth are found. Trees mainly found within the ecosystem are the different Acacia species. The ecosystem's main feature is the confluence of rivers Tana and Thiba, Kamburu and Masinga hydroelectric dams, which harbor variety of biodiversity (Chira, 2003).

Two islands within Kamburu dam (constructed in 1976) are part of the protected area. The southern boundary of the reserve is circumscribed by Tana River while the eastern boundary conforms to Thiba River. The northern boundary is delineated with an electric fence to protect animals from invading the Makima settlement as shown in Figure 3 below.

3.1.4. Management

MNR is co-managed between Kenya Wildlife Service and Mbeere County Council through a Memorandum of Understanding (MoU). An advisory committee oversees the implementation of management plans of the reserve making this arrangement to be unique in comparison with other reserves.

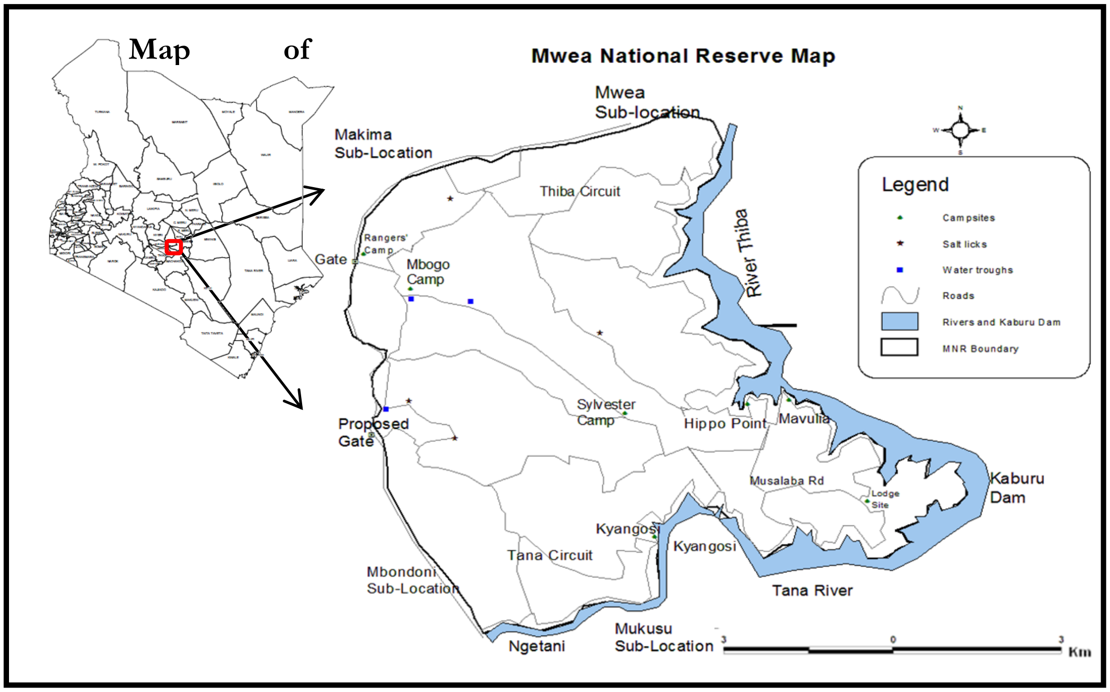

Figure 3: Mwea National Reserve Map (Source: Author, 2013)

3.1.5. Climate

The reserve has a hot and dry semi-arid climate with; temperatures ranging between 10 and 30 ^{0}C, occasional easterly winds and unevenly distributed bi-modal rainfall over the year with main peaks between March-April and October to January. The average annual rainfall is variable and ranges between 650 to 1000 mm (Chira & Kinyamario, 2009).

3.1.6. Mammalian Species

The reserve has over 20 mammal species (www.kws.org). They include: the savanna elephant (*Loxodonta africana africana*), impala (*Aepyceros melampus*), cape buffalo (*Syncerus caffer caffer*), defassa waterbuck (*Kobus ellipsiprymnus*), Hippopotamus (*Hippopotamus amphibius*), giraffe (*Giraffa camelopardalis rothschildi*) and burchell's zebra (*equus quagga burchellii*). The small ones are bush duiker (*Sylvicapra grimmia*), black-backed jackal (*Canis mesomelas*), bushbuck (*Tragelaphus scritus*), olive baboon (*Papio anubis*), Sykes' monkey (*Cercopithecus mitis albogularis*), serval cat (*Felis serval*), spotted hyena (*Crocuta crocuta*), warthog (*Phacochoerus africanus*), and rock hyrax (*Procavia johnstoni*).

The reserve has lost a number of common species to this eco-climatic region such as the black rhino, coke's hartebeest, lesser kudu, wildpig, lion, and leopard. Concerted efforts are being undertaken for their re-introduction, KWS in 2000 re-introduced the Rothschild's giraffe while in 2001, 30 Burchell's zebra were also re-introduced through the assistance of Bio-diversity Conservation Programme of the Community Development Trust Fund (Chira, 2002).

3.1.7. Vegetation Classification

The reserve's vegetation falls broadly under ecological zone 5 of (Pratt, Greenway, & Gywnne, 1966) classification (Chira & Kinyamario, 2009). The reserve has three distinct vegetation types: the bushland, woodland and wooded grasslands. The bushland vegetation type is dominated by *Acacia mellifera, Commiphora africana, Grewia bicolor* and *Acacia ataxacantha* (Chira, 2003). The woodland is dominated by *A. mellifera* and *C. africana* while the wooded grasslands are mainly under *Combretum sp* and *Terminalia browniiTerminaliabrownii* (Chira & Kinyamario, 2009).

3.2. Materials and Methods

3.2.1. Elephant distribution by dung count index

Elephant dung pile count on belt transect measuring 200 m length by 10 m width was used as an index of spatial and temporal distribution, general habitat preference utilization and elephant abundance (Komer & Brotherton, 1997). The results were expressed as dung piles per hectare (Chira, 2003). A vegetation grid map was used to systematically select 40 random sampling sites in the reserve as per the habitat-transect ratio given above. The coordinates of the selected points per strata were keyed in a GPS unit for location on the ground. Transect orientation from the starting point was determined by the nature of the topographic features of the area, with transects cutting across drainage channels. The bearing of transect was determined and a prismatic magnetic compass used to keep track of the centerline (100 m measuring tape). All the elephant dung piles within 5 m of either side of transects were counted and the perpendicular distance of each dung pile from the centerline measured with a measuring tape at an error of ±1 cm. They were also geo-referenced using a Garmin 12 channel GPS handset (projection: WGS-84 datum; Navigation: dd.mm; metric units) for spatial distribution analysis using fixed kernel probability contours.

The age of the elephant dung piles was categorized in five stages of decomposition: **Category-A**: boli intact, fresh, moist; **Category-B**: boli intact but dry; **Category-C**: about 50% of boli disintegrated; **Category-D**: all boli disintegrated, dung pile flat and homogeneous; **Category-E**: boli not visible from 2 m distance, almost completely decayed as demonstrated in appendix VIII (Barnes & Jensen, 1987).

3.2.2. Estimating elephant dung decay rates

Dung decay rates are highly variable between sites due to existing differences in rainfall regime, elephant diet and probably vegetation type hence they cannot simply be inferred between sites and seasons (Hedges & Tyson, 2002; Olivier et al., 2009). The aim was to estimate the mean rate of dung decay in MNR by measuring the time that each dung-pile in a sample takes to pass from deposition to category E. During the start of the dung count period, five fresh dung piles in each of the four main vegetation types were tape marked and monitored at irregular intervals for a period of eight weeks. On each visit, a photo was taken to aid in comparison and estimation of decay rates for all boli combined. Dung piles ranging from Stage A to Stage D of decomposition were defined as surviving and present, while those at Stage E or completely gone, were considered absent and not surviving (Barnes & Jensen, 1987). Other aspects affecting the dung state such as presence of dung beetles, termites, or the dung spread by other animals like Guinea fowls were recorded.

3.2.3. Elephant-woody vegetation interaction survey in MNR

Using a randomized block design 40 belt transects measuring 200 m length by 4 m width were selected from a vegetation grid map with the above calculated habitat-transect ratio for woody vegetation sampling. The selected transect starting points were input as way points in a GPS unit, then used to navigate to the point on ground and transect orientation determined by the nature of the topographic features of the area with transects cutting across drainage channels. With the use of a prismatic magnetic compass for measuring the bearing from the starting landmark, (i.e. taped big tree), a 100 m measuring tape was aligned as the center-line using the leader and follower method of alignment where the follower held the compass and directed the leader to keep on the track.

All the woody plants within 2 m of either side of transect were enumerated systematically and the following parameters recorded the plant species, main stem diameter, plant height, utilization status, utilization height, damage description and the cause of the damage. All trees with a diameter greater than 4 mm were identified, their diameter was measured at breast height or the mid-way below the main branching in mm (±1 mm) using a steel-tape measure and recorded. The height of the highest tip of the tree was measured using a tree-measuring rod in meters (±0.1 cm) as the tree height, if not clear which of the many protruding branches was the highest, their heights were measured and the highest value taken as the tree height. The measuring rod was positioned on a level ground with the base of the tree being measured: to avoid uneven ground that could introduce an error, and perpendicular to the branch top been measured. For trees taller than the measuring rod (7.6 m), they were classified as more than 7.6 m. The plant was inspected for any browse marks or damage on the main stem, crown or side branches. The utilization status of the tree was recorded as whether utilized or not utilized/ damage present or absent. Utilization height was measured and the utilization mode described. Elephant mode of utilization was classified as follows: main stem broken (100% removal of the crown), side branches broken (~50-75% removal of the crown), debarked, tree up-rooted or bend and browsed (<50% utilization); selective chewing of some parts without decapitating the branch or stem: as demonstrated in appendix IX (Wahungu et al., 2011). The damage was aged whether new or old by keen inspection of the damage site. Croze, stated that the age of damage could be categorized by inspection of the color and condition of the wood at the damage site (Croze, 1974). Fresh damage ranges from white color and wet/green to dry and yellow to brown in color while old damage is usually dark in color and some recovery of the bark is evident. Other observations were recorded such as browsed by other browsers like giraffes, tree attacked by termites, or tree drying up.

3.2.4. Effectiveness of MNR electric fence in control of HECs

Data on fence design, maintenance, and reinforcement was collected through direct observation, field measurement and discussions with the MNR staff members. The entire 16 km fence was surveyed during the study period. The fence line was marked with a GPS at intervals of 4 km or at any unique observation like corners, reinforcement and recorded in a field notebook for mapping. Data that was collected on every 4 km or at corner posts was, the posts' height, spacing between posts, number of strands, and other modifications added to improve its effectiveness. The voltmeter reading records were reviewed to find out the average monthly voltage of the fence over five years since 2008 to 2012.

3.2.5. Five years HECs records review starting from 2008 to 2012

MNR management by KWS and the Mbeere county council keep an occurrence book where all the reported incidences are recorded. This was used to review all reported cases of human-elephant conflicts after fencing of the reserve. Such cases included, but not limited to; elephant escape from the reserve, crop raids, injury to human or death, fence breakage and other property destruction.

For each case reported: date of occurrence, the nature of such case: crop raid, human injury or death, property damage, fence breakage the cause of the conflict, and the location where the incidence occurred. Locations of the incidences were later traced on the map and elephant pressure points identified for possible reinforcement recommendation options.

3.2.6 Determining the opinions of the local people on elephant conservation in MNR

The opinions of the local people around MNR are most likely to be influenced by the location of their homestead in reference to the reserve geographical setup. Those people living adjacent to the northern fence have experienced the periods of before and after fencing hence, can attest the significance of the fence in control of HECs. Residents along the Tana and Thiba rivers were a good control target population to evaluate the values of the fence against people who border the reserve side without fence. In addition, the closest neighbors to the reserve boundary bear the highest cost of HECs, so the research targeted residents living within 500 m from the boundary along the electric fence and Tana River.

Stratified random sampling technique was used to select 120 homesteads within the defined sampling frame: 60 homestead questionnaires in the fenced side and 60 in the un-fenced side along Tana River. With the aid of six trained local enumerators, the questionnaires were administered to adult residents of the defined sampling frame, preferably the head of the family who had lived in the area for more than ten years. A pair of enumerators was given a section to administer 20 questionnaires randomly per that block in a day.

3.2.7 Data Collection

The research was carried out in late January to mid-March 2013, which was a dry season in the area. For proper orientation and understanding of the reserve’s ecological setup a one-week, reconnaissance of the entire reserve and the Makima village was done in mid-January 2013. This was important in gathering background information on the stratification of the study area and the selection of the sampling sites. The reserve’s vegetation was stratified into four distinct classes: the bushland, *Acacia mellifera* woodlands, *Commiphora* *africana* woodlands, and wooded grasslands (Chira, 2003). During the survey, two sample belt transects measuring 200 m length by 10 m width on each habitat cutting across the drainage were done to determine the mean dung pile variance. The transects distribution ratio per habitat was then calculated proportionately to the mean dung pile variance since variance is proportional to density (Kadzo Kangwana, 1996). Transects were distributed among the four vegetation types as follows: 0.3:0.25:0.25:0.2, *Acacia mellifera* woodland: *Commiphora africana* woodland: Wooded grasslands: and Bushland, respectively. Sampling frame for all possible sites per habitat using a grid vegetation map was developed from which sampling sites were randomly selected. Five fresh elephant dung piles in each habitat were identified flagged and coordinates taken using a Global positioning System (GPS) unit for subsequent dung decay monitoring.

The assumption was that the reserve was in a ‘steady state,’ which means that no elephants moved in or out of the study area, and the rates of dung deposition and decay have remained constant for a long period before the count and also while the count was taking place (Barnes & Jensen, 1987). This steady state theory requires that dung counts be done either in the wet season or the dry, but neither both or during the transition period between seasons (Olivier et al., 2009).

3.2.8 Data Analysis

Data management was done in MS. Excel spreadsheets and all statistical tests done using **S**tatistical **P**ackage for **S**ocial **S**cience (IBM® SPSS® version 20.0.0) software. All tests being two-tailed and alpha set at 0.05, parametric tests were done where the data distribution satisfied the criteria of normality and homoscedasticity. For instance, one-way analysis of variance (ANOVA), *F*- test, was used to compare means of the ranks of independent variable. It was applied on categorical independent variable against quantitative dependent variable, for example, habitats (four types) against the dung density. The descriptive statistics: mean (M), standard deviation (SD), and standard error (SE) were used to present the results in form of graphs.

G-test and Pearson's Chi square test (χ^2) for independence were used to test for associations between two categorical variables. For instance, to determine the relationship between the preferred woody species and the height classes utilized by elephants. The sample data was displayed in a contingency table with one categorical variable on the rows (r) and the other on the columns (c). The degrees of freedom (DF) was calculated by: DF = (r - 1)*(c - 1). Where, r is the number of levels for one categorical variable, and c is the number of levels for the other categorical variable. The tests were done where no more than 20% of the expected counts were less than expected minimum value (Yates, Moore, & McCabe, 1999). The tests were run using SPSS and the frequencies of the variables presented in bar graphs.

The non-parametric, Spearman rank-order correlation coefficient test was used to measure the strength and direction of association between the counted numbers of elephant dung piles and utilized preferred plants per transect. Kernel Density Estimation (KDE) techniques in geospatial analysis are applied to point datasets with spatially extensive attributes (DE Smith, Goodchild, & Longley, 2007) in Geographic Information Systems (GIS) to give a raster dataset (Longley, Goodchild, J., & Rhind, 2005) where each cell has a density value that is weighted according to distance from the starting features. More formally, Kernel estimators smooth out the contribution of each observed data point over a local neighborhood of that data point. The contribution of data point x(i) to the estimate at some point x* depends on how apart x(i) and x* are. The extent of this contribution is dependent upon the shape of the kernel function adopted and the width (bandwidth) accorded to it. However, this brings a challenge of smoothed curves to overlap the limits. Using GIS software (ArcView 3.3) fixed Kernel; Probability contours were constructed to generate elephant dung density distribution pattern (Silverman, 1986). Map highlighting areas of intensive elephant dung density as core range of elephant use were those with 50% of dung density, 50-75% as medium ranges and 75-95% as the low ranges of elephants' utilization in the reserve.

Linear dung decay models were fitted through maximum likelihood to the dung decay data and used R^2 values to choose the model that best represented the MNR dung decay rate. This model allowed for the estimate of average decay period (Olivier et al., 2009).

Elephant preference for forage woody species was calculated using preference ratio (PR) (Chira & Kinyamario, 2009; Tchamba, 1995). To determine and distinguish between preferred woody species from those not preferred in relation to elephant utilization, preferred species was defined as a species that was utilized proportionately more frequently by elephants than its abundance in the immediate environment (Chira & Kinyamario, 2009; Viljoen, 1989). Preference ratios for the different plant species utilized by elephants were calculated using the following equation (Viljoen, 1989).

$$\text{Preferential ratio (PR)} = \frac{\text{Percentage utilization(U)}}{\text{Percentage availability(A)}}$$ Whereby:

$$\text{Percentage utilization(U)} = \frac{\text{Number of fully utilized woody plants of a given species per unit area}}{\text{Total number of fully utilized woody plants of all species within the same area}} * 100$$

$$\text{Percentage availability (A)} = \frac{\text{Number of available woody plants of a given species per unit area}}{\text{Total number of available woody plants of all species within the same area}} * 100$$

The preferential ratios obtained centered on 1 as a reference Point (Chira & Kinyamario, 2009). Woody species with preference values above one were those that were sought out as preferred foods by elephants. A rating of below one represented those species that were avoided as food. Species with a preference ratio of exactly one were neither preferred nor avoided but were eaten precisely in proportion to their abundance. Species that were totally avoided had a zero preference ratio (Chira & Kinyamario, 2009; Viljoen, 1989).

CHAPTER FOUR

RESULTS

4.1. Elephant distribution, habitat use, and preference

Using the total 508 counted in the 40 transects and geo-referenced dung piles as an index of elephant distribution and habitat use, fixed Kernel estimation showed that elephants in MNR preferred the areas close to the main rivers: the Thiba and Tana Rivers while avoiding the western fenced periphery as shown in Figure 4 below. Appendix I shows distribution of transects per habitat and dung density/ha. The elephants of MNR are cryptic and spend most of their time in the bushland and woodlands; they seldom foraged on the grasslands during the day and therefore, not frequently encountered.

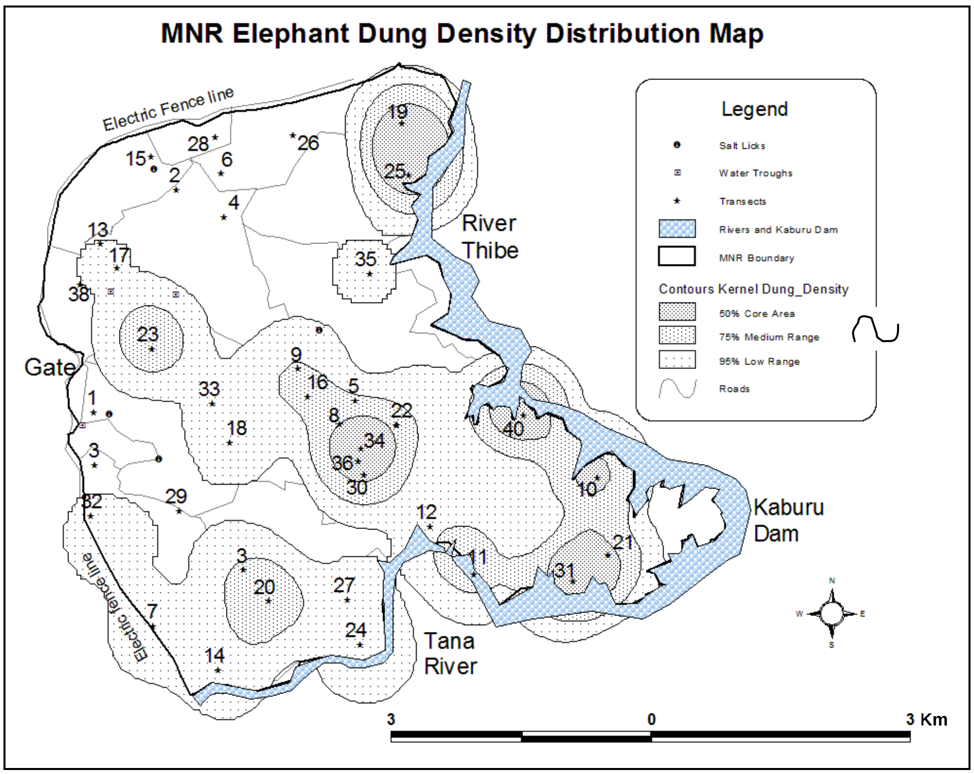

Figure 4: Elephant dung density distribution in MNR (Source: Author, 2013)

A one-way ANOVA test was used for differences in dung density distribution in the vegetation types. There was a significant difference in the dung densities across the four habitats ($F_{(3, 36)} = 7.36$, $p<0.001$). The bushland had the highest dung/ha (M=120.63, SD=89.10) followed by *Acacia mellifera* habitat (M=80.42, SD=62.36), *Commiphora africana* habitat (M= 58.00, SD=32.85), with wooded grassland habitat (M=3.00, SD=5.37) having the least density, Figure 5.

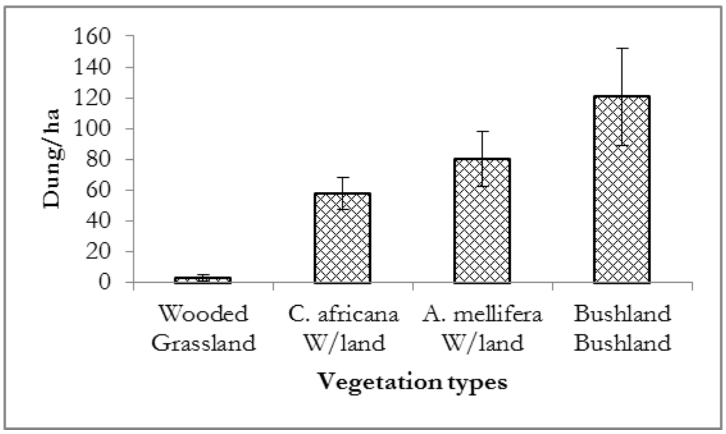

Figure 5: Elephant dung/ha for each vegetation type (Error bars= SE)

A linear dung decay model, y = 0.03x + 12.44, R^2= 0.16 estimated an average decay rate of 12.80±6.46 days/stage (Figure 6). Therefore, fresh elephant dung in MNR takes approximately 51.2±25.84 days to decay from deposition stage A through to E during the dry season as demonstrated in appendix VIII.

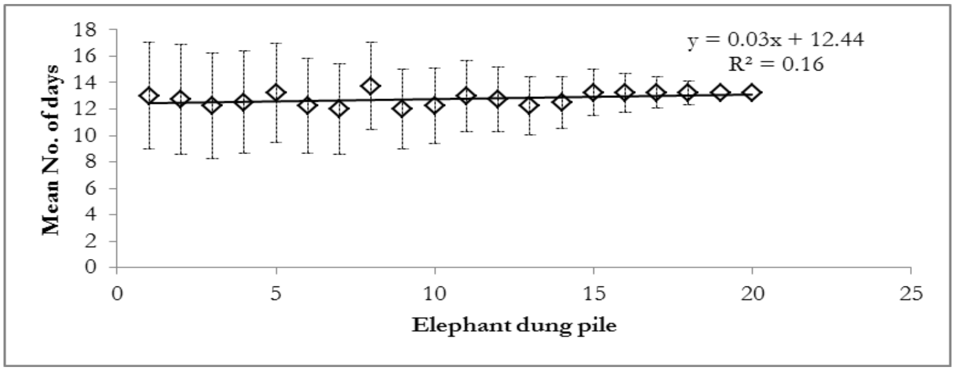

Figure 6: MNR Elephant dung decay rate linear model (Error bars= SE)

One-way ANOVA test was used to examine for differences in dung decay rates per habitat. There was no significant difference in the dung decay rates across the four habitats ($F_{(3, 80)}$ = 0.51, p =0.985). The wooded grassland habitat had slightly longer decay period (M=13.25, SD=7.28) followed by bushland and *Acacia mellifera* woodland habitats with equal decay rates of M=12.75, SD=6.57 and finally, the *Commiphora africana* habitat (M= 12.45, SD=5.83).

One-way ANOVA test was used to test for differences in dung decay rates per category. The dung decay rates per category were significantly different ($F_{(3, 80)}$ = 392.22, p <0.000). Decay category B had the longest decay period in days (M=21.15, SD=2.11) followed by category C (M=16.4, SD=2.11), category D (M=7.4, SD=0.75) and finally, category A (M= 6.25, SD=1.02), Figure 7.

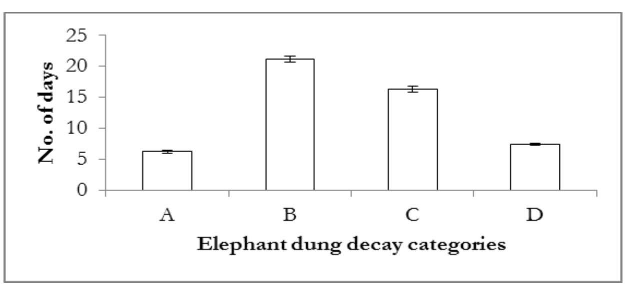

Figure 7: Dung decay rate per category (Error bars= SE)

G-test of independence was used to determine whether elephant dung decay stages distribution was equal in the four habitats. The elephant dung decay stages were significantly unequal in distribution across the habitats ($G_{(12,\ N=\ 515)}$ =28.47, p<0.005). Bushland and *Commiphora africana* woodland habitats had the highest overlap of all of the five decay categories followed by the *Acacia mellifera* woodland that had category A missing. The wooded grassland had only two decay categories represented, B and C as illustrated in Figure 8.

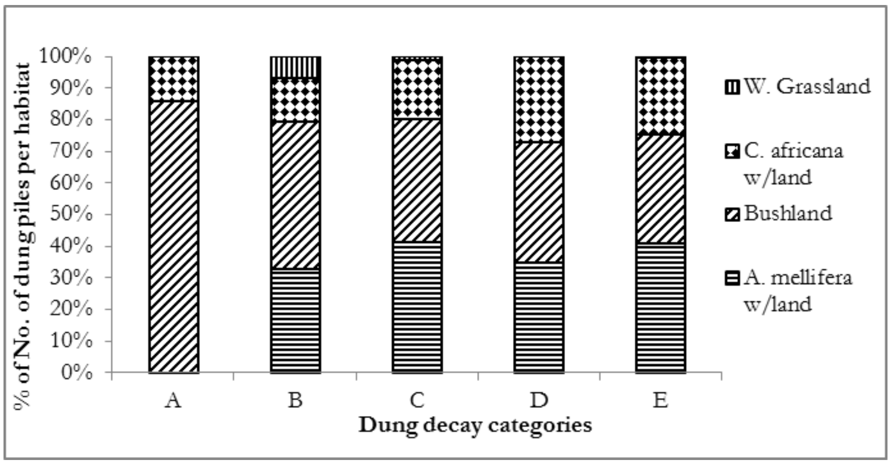

Figure 8: Elephant dung decay categories per habitat

4.2. Impacts of elephants on woody vegetation structure and species composition in MNR

Four thousand, three hundred and one trees of the 31 enumerated woody species were sampled during the dry period ranging from late January to mid-March 2013. On average, the elephant utilized 41% of the trees sampled with the highest utilization proportion occurring in the *Acacia mellifera* woodland and the bushland. Elephants preferably utilized *Acacia ataxacantha* the most; 55%, followed by, *Acacia brevispica;* 52%, *Acacia tortilis*;

51%, *Grewia bicolor*; 33% *Acacia etbaica* 32% and *Grewia tembensis,* 28%. Out of the 31 woody species enumerated: *Acacia ataxacantha, Acacia brevispica, Acacia tortilis, Grewia bicolor, Acacia etbaica* and *Grewia tembensis* were the main preferred forage by elephants (PR>1). *Acacia mellifera, Grewia villosa, Ormocarpum kirkii, Commiphora africana, Acacia hockii, Combretum aculeatum, Lantana camara, Grewia truncate, Maytenus putterickioides* species were avoided as food relatively to their availability and utilization (0>PR <1) as shown in Figure 9 below. Those species, which were totally avoided as food (PR=0) are listed in appendix III.

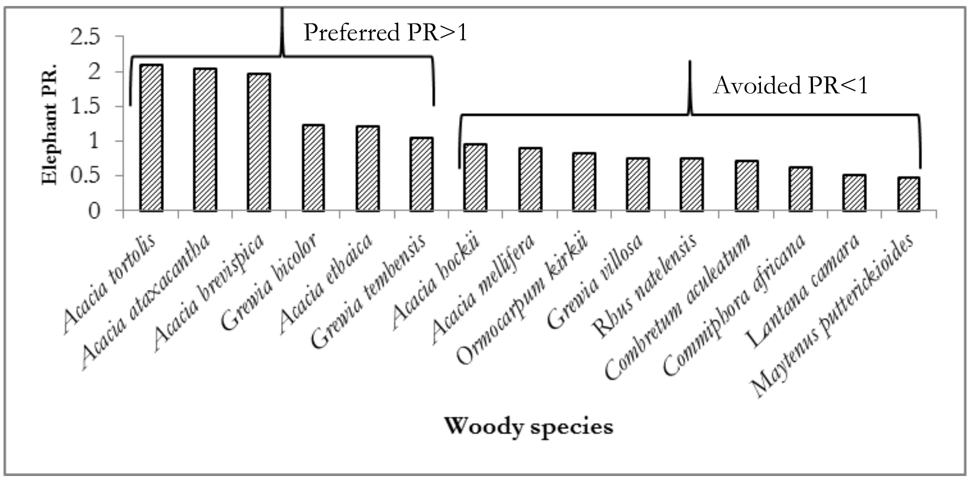

Figure 9: Elephant utilization preferential ratio for woody species in MNR

G-test of independence tested whether the woody species distribution in the four habitats was equal. The woody species availability was not equal in the four habitats ($G_{(90,\ N=4301)}$ =2991.06, $p<0.0001$). *Grewia bicolor, Acacia ataxacantha,* and *Grewia tembensis,* dominated the bushland while in the *Acacia mellifera* woodlands *Grewia bicolor, Acacia mellifera, Grewia tembensis,* and *Grewia villosa* were common. *Commiphora africana, Grewia villosa, Acacia mellifera, Grewia tembensis,* and *Grewia bicolor,* dominated the

Commiphora africana woodlands and in the wooded grasslands: *Ormocarpum kirkii, Combretum aculeatum, Acacia hockii, Commiphora africana* and *Maytenus putterickioides* were the majority as shown by their densities in appendix II. The six preferred woody species together with *Grewia villosa* which was of key interest to this study cumulatively formed >65% of the *Acacia mellifera* woodlands and bushland, 50% in *Commiphora africana* woodlands, and only 3% in wooded grasslands as shown in Figure 10.

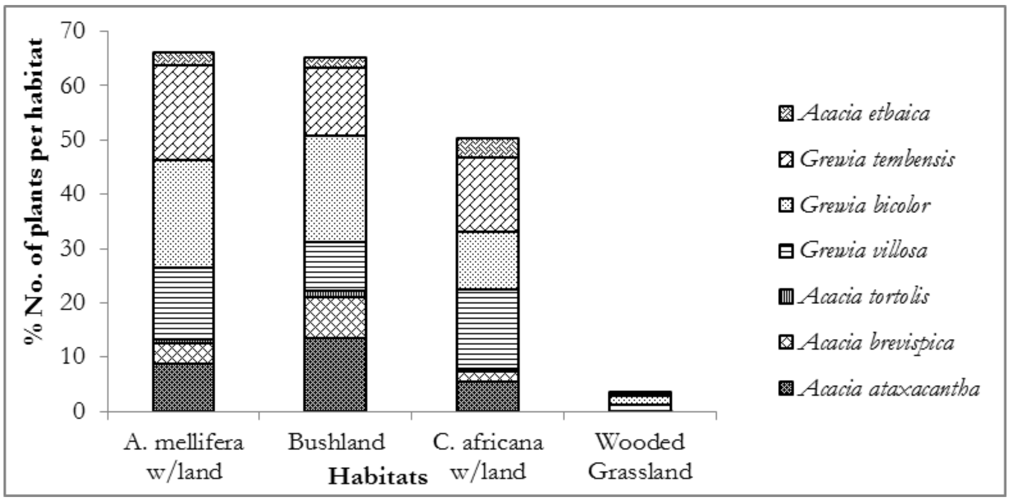

Figure 10: Preferred woody species distribution per habitat

A Spearman's Rank Order correlation coefficient was run to determine the relationship between the counted elephant dung piles and utilized preferred plants per hectare in the 40 transects. There was a strong, positive correlation between elephant dung density and the level of utilization of the preferred species (Figure 11), which was statistically significant ($r_{s(40)} = 0.795$, $p<0.0001$).

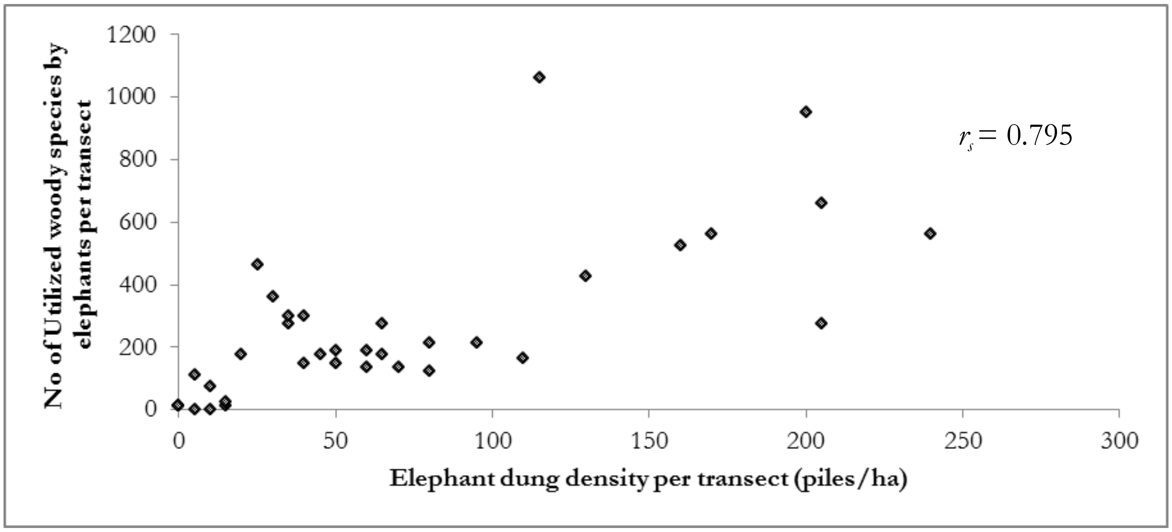

Figure 11: Association between elephant dung piles and the utilized preferred species per transect

Utilized plant height and elephant utilization height were analyzed by means of one-way between-subjects ANOVA test for the seven species. The mean height of the utilized plants for each of the seven species were significantly different ($F_{(6,\ 749)}$ =42.27, *p<0.0001)*. Except for the *Acacia tortilis* and *Acacia etbaica,* the other species were confined within 3 m mean height. *Acacia tortilis* (4.49±2.37 m) was the largest followed by *Acacia etbaica* (4.27±2.42 m), *Acacia brevispica* (3.04±1.22 m), *Grewia bicolor* (2.44±0.88 m), *Acacia ataxacantha* (2.30±1.20 m), *Grewia tembensis* (1.88±0.93 m) and *Grewia villosa* (1.59±0.58 m), Figure 12. Elephants utilized the species at significantly different heights ($F_{(6,\ 749)}$ =32.03, *p<0.0001)*. *Acacia tortilis* (2.41±1.57 m) was utilized at the highest level followed by *Acacia etbaica* (2.18±1.30 m) *Acacia brevispica* (2.12±0.89 m) *Acacia ataxacantha* (1.76±0.87 m) *Grewia tembensis* (1.28±0.70 m) *Grewia bicolor* (1.23±0.88 m) and (0.81±0.38 m) for *Grewia villosa*, Figure 12.

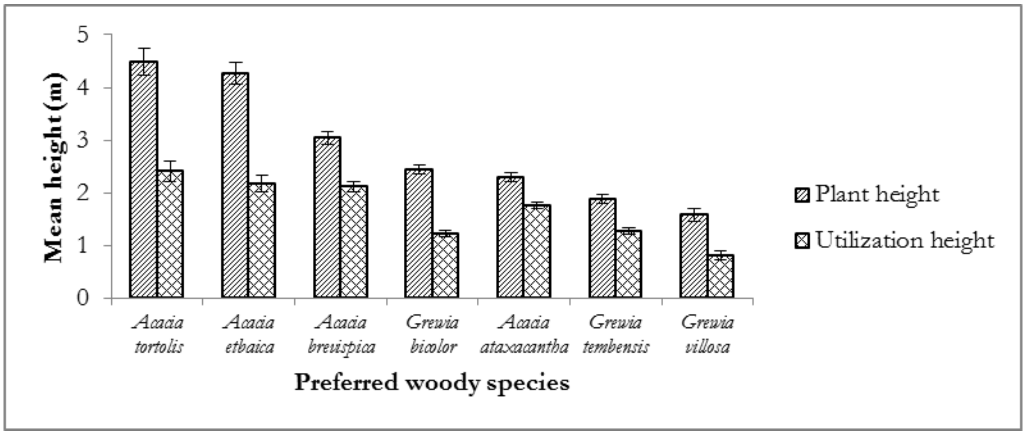

Figure 12: Plant and elephant utilization mean heights of the utilized preferred species (Error bars= SE)

The individual height of the woody species was ordered into four height classes; 0.01-0.50, 0.51-1.50, 1.51-3.00 and >3 m. G-test of independence was performed to examine if the seven woody species had equal representation of the four height classes. The height classes were significantly different in the seven species ($G_{(18,\ N=2231)}$ =520.41, $p<$ 0.000). On average, the 1.51-3.00 m height class was the most represented in the seven species with 50%, followed by 27%, 0.51-1.50 m, 21% >3.01 m and only 2% for the 0.01-0.50 m seedlings height class, Figure 13.

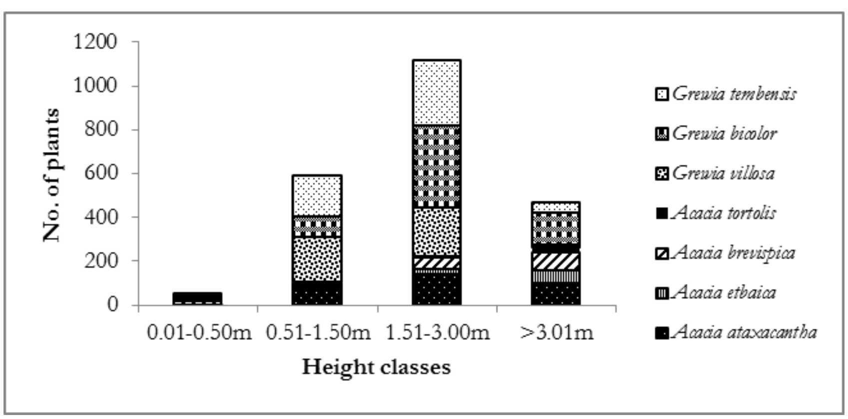

Figure 13: Height classes per woody species

G-test of independence was performed to examine whether elephants utilized the four height classes of the seven species equally. Elephants' utilization level of the four height classes of the seven species was significantly not equal ($G_{(18, N=756)}$ =180.31, $p< 0.000$). The 1.51-3.00 m height class was the most utilized (51%) followed by >3.01 m height class (24%), 0.51-1.50 m (23%) and only 2% for the 0.01-0.50 m seedling height class (Figure 14). Cohorts of *G. villosa* were missing in the >3.01 m height class (Figure 14).

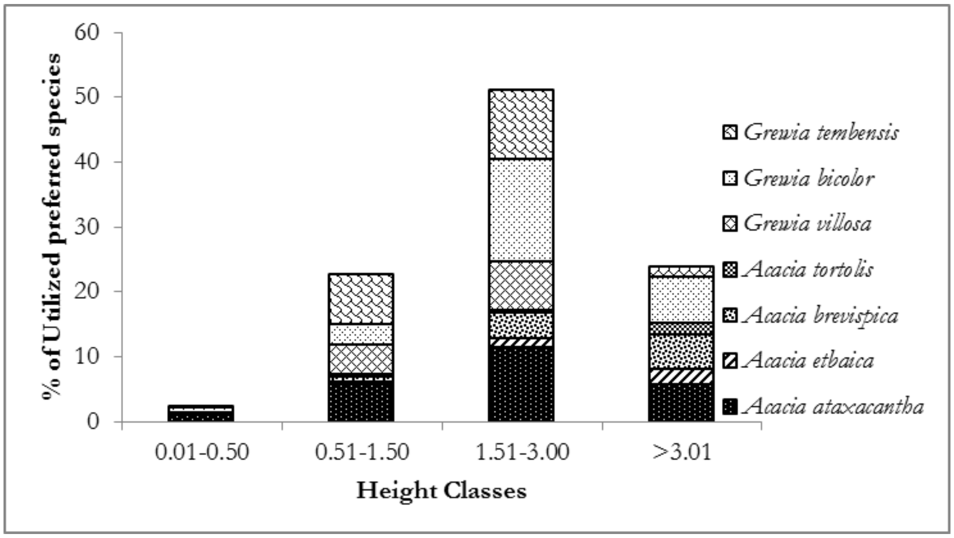

Figure 14: Utilized height classes per woody species

G-test of independence was done to determine whether elephants utilized the seven woody species in the same mode. Elephants significantly utilized their preferred plant species differently, ($G_{(18, N=756)}$ =178.23, $p< 0.0001$). Elephants mainly, >93%, browsed the shrub species *Acacia ataxacantha, Acacia brevispica, Grewia bicolor*; *Grewia villosa* and *Grewia tembensis*. The large woody trees were utilized in varying modes; *Acacia etbaica* was 23% browsed, 58% main stem broken and 3% uprooted or bend. *Acacia tortilis* trees were; 16% browsed, 21% debarked, 58% main stem broken and 5% uprooted or bend over, Figure 15.

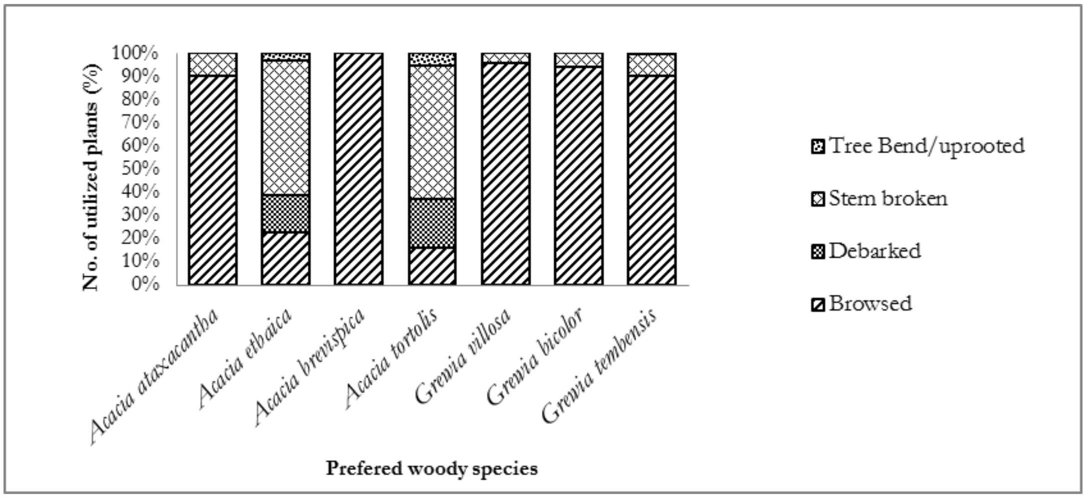

Figure 15: Mode of elephant utilization per preferred woody species

Dung density and mean height of preferred plants

Pearson correlation test was run to determine the relationship between elephant dung density per transect and the mean height of the preferred species in transects that they occurred. The mean height of the three most preferred species (>50%) correlated slightly negatively with the elephant dung density per transect *Acacia ataxacantha* ($r_{(N=30)} = -0.096$), *Acacia brevispica* ($r_{(N=19)} = -0.202$) and *Acacia tortilis* ($r_{(N=19)} = -0.182$).

The mean height of the four other preferred species whose utilization was less than 35% correlated positively with the elephant dung density per transect *Grewia Villosa* ($r_{(N=32)} = 0.434$), *Acacia etbaica* ($r_{(N=23)} = 0.693$), *Grewia bicolor* ($r_{(N=32)} = 0.250$) and *Grewia tembensis* ($r_{(N=32)} = 0.319$).

4.3 Effectiveness of the MNR Electric fence in control of human- elephant conflicts

Principally, the MNR electric fence has two solar powered strands. The solar generated DC is boosted to an average of 5.38±0.53 kV AC. One neutral strand at the middle of the two live wires on top of the lower six barbed wires closely fixed on 7 feet tall wooden posts (and some few plastic posts) at intervals of 8.25 m apart and reinforced corner posts as shown in **Error! Reference source not found.**.

Plate 1: MNR electric fence outline showing a reinforced corner post (Source: Author, 2013)

Survey of the 16 km electric fence found no special modification of the fence from the general design. Scrutiny of the occurrences books (OB) and fence maintenance books revealed that there has never been a single incidence of elephants breaking the electric fence to escape from the reserve. The following were the identified challenges that face the MNR electric fence maintenance: fence posts destruction by termites, theft of barbed wire on the Thiba circuit, short-circuiting by people, destruction of plastic posts by solar radiation and the regular fence line clearance of undergrowth, and overgrowing plants.

Since 2008, the OB records showed no incidence of HECs in the fenced side of Makima location but, varying numbers of HECs in the unfenced sides along the Tana and Thiba rivers. Linear regression revealed a significant positive relationship between the HEC cases and time, on the Thiba riverside (R^2 =0.84, P<.0001). Independent sample T-test was done to compare the number of HECs along the two rivers. Tana River side (9.60±4.77) had significantly higher HECs than Thiba riverside (2.60±2.40), ($t_{(4)}$ =3.80, p=0.019). Both riversides had the highest record of HECs in the year 2010. When regressed against the elephant populations for the 5 years, the HECs significantly related positively, (y = 0.56x - 34.09), (R^2 = 0.25), as shown in Figure 16.

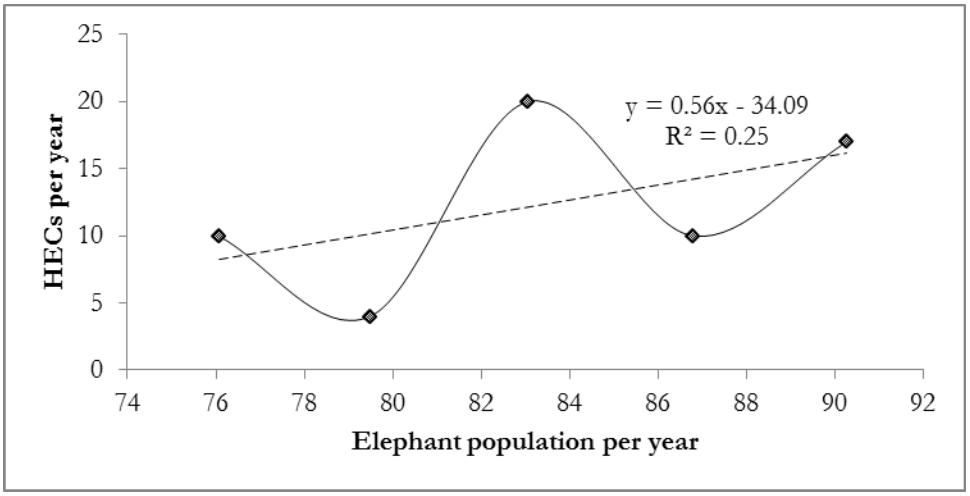

Figure 16: Annual HECs against elephant population

4.4. MNR local community Opinions on the conservation of elephants

A total of 111 questionnaires were adminstered out of 120 target; a 92.5% achievement with 50 questionnaires in the unfenced side and 61 in the fenced side of the reserve. Analysis factored 90 questionnaires which were duly filled up: 45 from each block.

Respondents background information: 53% of the respondents were males and 47% females. 93% of them had been residents of the area for over 10 years while 83% lived there before the fence was constructed in 1998.

4.4.1. Opinions on HEC occurrence and fence effectiveness in control of the HEC

The residents were asked if before and after fencing elephants did escape and if they continue to do so from the reserve into their farmland. Pearson's chi-squared test of independence was done to compare whether the response was similar in both sides. The elephants invaded the residents farms before fencing of the reserve since Pearson's chi-squared test of independence showed no signifcant difference in response between the fenced and unfenced areas $\chi^2_{(2,\ N=90)}=4.10$, $p=0.12$. Ninety seven percent of the respondents from the fenced side agreed that the elephants invaded their farms before the fencing of the reserve while 86% from the unfenced side also conceded the same. There was a significant variation in the response on whether elephants invade farms after the fence ($\chi^2_{(1,\ N=90)}=5.38$, $p=0.020$). Thirty eight percent of the respondents from the fenced side of the reserve reported that elephants still invade their farms even after the fencing while 62% of the respondents on the unfenced Tana riverside reported the same.

The elephants escape ways from the reserve into the farmlands known by the respondents were listed and Pearson's Chi- squared test of independence done to determine whether they were same in the two sides of the reserve. There was a significant difference in the escape methods reported from the two blocks ($\chi^2_{(2,\ N=90)}=64.98$, $p<0.0001$). Eighty two percent of the respondents from the fenced side were not aware of how the elephants escaped the reserve while 98% of the respondents from the unfenced side and 13% from the fenced side reported crossing across the river as the main escape route.

The losses suffered from elephant invasion into their farmlands was tested using pearson's Chi-squared test and there was a significant difference in the losses caused by the elephants to the residents ($\chi^2_{(4,\ N=90)}=19.30$, $p=0.001$). The main losses listed were crop damage in farms, death to livestock and people, property damage such destruction of grain stores, irrigation channels and pipes and finally threat to life: risk of deterring elephants at night and fear of coming across elephants especially for school going children. Crop damage was the highest loss reported with 73% from the unfenced side and 33% from the fenced side. Death to live and threat to life were highly recorded in the fenced side mostly by those people living near the open ends of the river. Property damage was only reported in the unfenced side of the reserve, Figure 17.

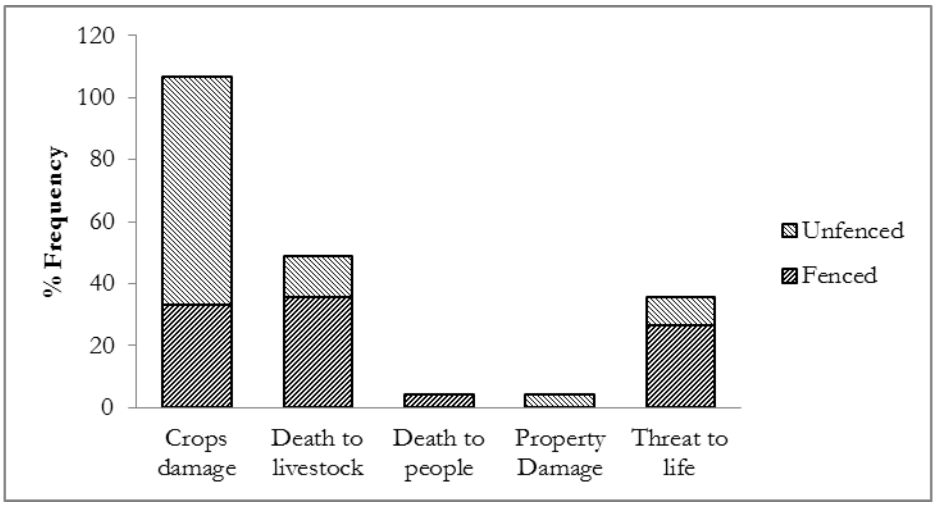

Figure 17: Losses caused by elephant invasion to the residents around MNR

The community's opinions on whether the reserve's electric fence helped in mitigation of HECs differed significantly $\chi^2_{(1,\ N=90)}$ =29.11, $p<0.00011$ in both areas. In general, 76% of the total respondents attested that electric fence is a good mitigation measure. All the respondents (100%) from the fenced side unanimously reported that electric fence controls HECs while 51% from the unfenced side were of the same opinion with the rest (49%) being of the contrary opinion.

The respondents were asked if KWS has put up other HECs mitigation measures apart from the fencing. The response from the two sides of the reserve did not vary significantly as found out by Pearson's Chi- squared test of independence ($\chi^2_{(3,\ N=90)}$=3.85, p=0.183). The responses from both sides were quite similar with 56% from fenced side and 64% from unfenced side saying that KWS does nothing to mitigate HECs as shown in table 1.

Table 1: KWS efforts to mitigate HWCs

KWS Mitigation efforts	Fenced side	Percentage	Unfenced side	Percentage
None	25	**56%**	29	**64%**
Control elephant Movement	7	**16%**	11	**24%**
Partial Compensation	4	**9%**	2	**4%**
Minimal efforts	9	**20%**	3	**7%**
Total	45	**100%**	45	**100%**

4.4.2. Local intervention measures to curb HECs

Local intervention measures the residents used to deter elephants from invading their farms varied significantly ($\chi^2_{(4,\, N=145)}$ =26.12, *p<0.0001)* in both sides of the reserve. Over 50% of respondents from both sides reported that they scare away the elephants by making noise: beating drums and shouting. 43% from the unfenced side reported use of fire, torches or burn chili and only 9% from the fenced side call KWS for support as shown in Figure 18.

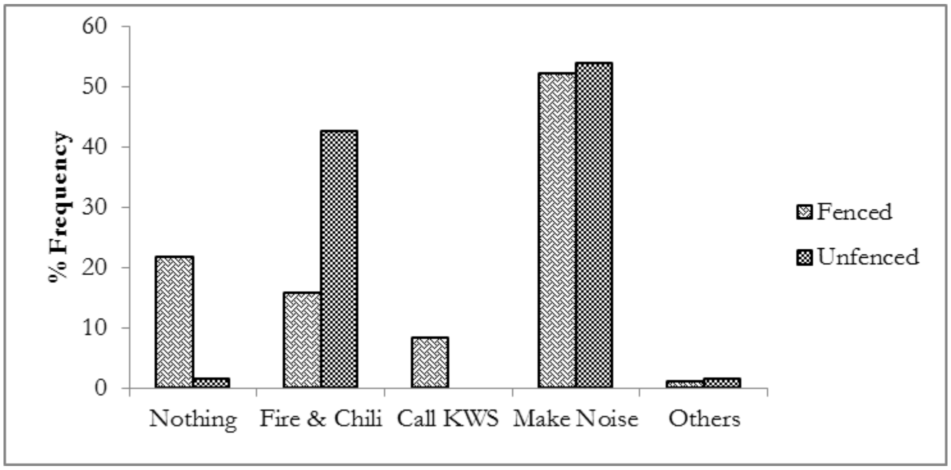

Figure 18: Residents' local elephant deterring methods

4.4.3. Other conflict causing wildlife

Other wildlife species other than elephants reported to create conflicts with the residents were significantly different in the two sides of the reserve ($\chi^2_{(6,\ N=204)}$ =231.15, *p<0.0001)*. Hippopotamus and crocodiles were the main problem animals in the unfenced riverside with 50% and 36% respectively while primates: baboons, Sykes and Vervet monkeys and antelopes were the trouble causing species in the fenced side with 29% and 22% respectively as shown in Figure 19.

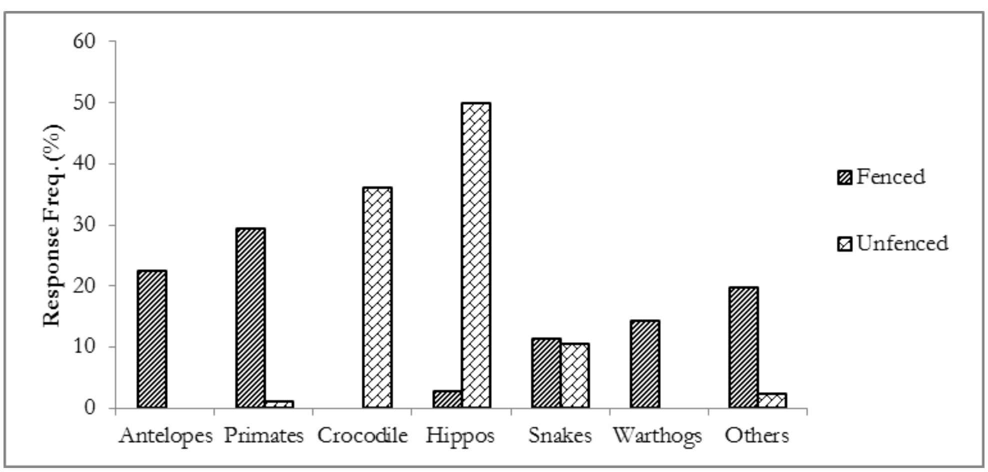

Figure 19: Other conflict causing wildlife

4.4.4. Benefits gained from the reserve and community expectations

The benefits gained by the local people from the national reserve were significantly different in the two areas ($\chi^2_{(6,\ N=120)}$ =24.44, *p<0.0001)*. Ninty one percent of the respondents from the unfenced side of the reserve were of the opinion that they don't get any benefit from the reserve while 47% of their counter-parts subscribed to the same opinion. The following are the benefits listed by the respondents from the fenced side: roads maintainance; 6%, jobs opportunities; 6%, school and educational support; 5%, water supply; 8%, environmental conservation and aesthetic beauty; 18% and community health and welfare; 9%.

The residents' expectations to the national reserve management from the fenced side of the reserve differed significantly from those of the people in the unfenced side of the reserve ($\chi^2_{(11,\ N=285)}$ =42.25, *p<0.0001)*. Residents from both sides of the reserve highly expected the reserve management to support schools, education and infrastructure development; however, both sides differed on their expectations on curbing of HWCs, job opportunities, community health support and control of Tse-Tse flies as indicated in table 2.

Table 2: Community expectations

Community expectations from MNR	**Fenced side**		**Unfenced side**		**Grand Total %**
	Freq.	**R. Freq %**	**Freq.**	**R. Freq %**	
Curb HWS	4	**2**	13	**11**	**6**
Disband the reserve	4	**2**	1	**1**	**2**
Sch. and Education Support	29	**17**	22	**19**	**18**
Water supply	28	**16**	14	**12**	**15**
Jobs	21	**12**	1	**1**	**8**
Community Health	6	**4**	13	**11**	**7**
Infrastructure dev.	35	**21**	22	**19**	**20**
Fencing and fence Up grade	18	**11**	9	**8**	**9**
Control of Tse Tse flies	3	**2**	12	**10**	**5**
Resource access	3	**2**	2	**2**	**2**
Public awareness	9	**5**	3	**3**	**4**
Compensation	10	**6**	3	**3**	**5**
Total	**170**	**100**	**115**	**100**	**100**

CHAPTER FIVE

DISCUSSION

5.1. Elephant Distribution in MNR

Bushland in MNR majorly occur at the transitional zones such as between the riverine woodland and the *Acacia mellifera* or the *Commiphora africana* woodlands. *Grewia bicolor, Acacia ataxacantha, Grewia tembensis* and *Grewia villosa* were common in these three habitats unlike in the grassland and these woody species were the most preferred forage by the elephants. Areas with high dung count correlated positively with the number of utilized plants. Elephant populations occur in discrete units; each of which shows a series of highly contagious instantaneous distributions which, when averaged over a period of time, probably tend, in a uniform habitat, to approach a random or regular distribution (Laws, 1970). The elephants of MNR are cryptic and spend most of their time in bushland and woodlands. Elephants spends much time in thickets foraging to accommodate their bulky feeding and high nutrients requirements (De Boer et al., 2000), or to seek refuge from disturbance from people and vehicles, and to escape from high direct solar radiation (Olivier et al., 2009 ; Van Aarde & Jackson, 2007). These elephants seldom foraged on the grasslands during the day and therefore, not frequently encountered. Examination of the dung densities showed that elephants in MNR significantly preferred the bushland and the woodlands while they tended to avoid the grassland. Therefore, food availability, refuge, and shade are the probable reasons for the elephant high preference of the bushland and woodland areas in the reserve.

Fixed Kernel buffers on dung density inferred a patchy elephant distribution pattern confined within the Thiba and Tana River proximities as well as the main tributary at the center of the reserve extending to the artificial water points as shown in the map. Studies have established that water availability and distribution are the most important factors affecting, or limiting elephant local movement (Laws et al., 1970; Poche, 1974; Weir, 1972). Elephants prefer to gather in close proximity of the main rivers (Stokke & Du Toit, 2002). The availability of surface water, floodplains, the ecotones and sodic sites associated with main rivers provide nutritional and habitat benefits that are not always found in the vicinity of artificial waterholes (Stokke & Du Toit, 2002). Bulls are evenly distributed with regard to surface water sources than mixed groups (Stokke & Du Toit, 2002). This could account for the high- density aggregation of elephants in habitats close to the two main rivers as well as the tributary and the low densities in the open wooded grassland whereby there are artificial water holes and salt licks.

Comparison of several studies on elephant dung decay rates in different sites in Africa yielded to a decay range of between 43–167 days (Olivier et al., 2009). In MNR, dung decay rate was 51.2±25.84 days. This was thus similar to other studies done elsewhere in Africa. Retrospectively, this can be used to tell how frequent elephants use a given area and habitat. The bushland, *Commiphora africana* and *Acacia mellifera* woodlands are the most frequently utilized habitats across the year and seasons in a descending order respectively. Accumulation of high proportions of old disintegrated dung category E (50%) in the three habitats and increasing numbers of the other decay categories the least represented being the freshly deposited dung category A shows that the elephants continuously used these habitats. The exception in the wooded grassland indicates that this habitat is the least utilized except preferably in the wet season by a small proportion of the elephant population. With dung decay rate of 64.8±19.75 days, dung deposited towards the end of the wet season in December 2012 and early January 2013 was in categories B or C in early February 2013. This explains the high percentage of category B (30%) in the wooded grassland, which implies some slight preference of this habitat in wet season.

The seasonal use of habitat is an important mechanism of survival and optimum utilization of resources, while at the same time reducing the impact on dry season habitat (Viljoen, 1989). MNR elephant population used to exhibit these seasonal movements before the erection of the electric fence in 1998 (Chira, 2005). High degree of overlap of all dung decaying categories and the accumulation of old disintegrated dung in the bushland, *Commiphora africana* woodlands and *Acacia mellifera* woodlands showed continued utilization of these habitats with little or no seasonal variability. This finding is further supported by a similar one by (Chira, 2005) whereby, he found that MNR elephants did not show seasonal variability in habitat use round the year.

5.2. Impacts of Elephants utilization on woody species in MNR

The woody vegetation structure of MNR

The woodlands and bushland of MNR had poorly defined boundaries and closed dense undergrowth confined within 3 m height. Elephants capitalize on the strong coppicing ability of damaged plants to maintain selected tree species at optimal height for browsing, while allowing non-selected species to grow to canopy height (Jachmann & Bell, 1984). This explains why elephants mostly preferred these habitats since the dense understory was composed of the preferred woody species and the canopy by the avoided ones such as the *Acacia mellifera, Commiphora africana* and the *Combretum sp*.

Over 80% seedlings and saplings mainly of *Ormocarpum kirkii* and *Acacia hockii* dominated the grassland (appendix II). Sparsely spaced mature *Combretum* and *Terminalia sp* trees and a prominent grass sward were also common in the grassland. Less than 5% of the elephants' preferred species formed the grassland hence the reason why the elephants avoided this habitat. This grassland was the prime habitat for the giraffe and the zebra the impala and the buffalo also show high seasonal preference (Chira, 2003). The MNR wooded grassland is challenged with serious threat of a high recruitment proportion of woody plants mainly invading from the woodlands of the reserve. Similarly, there are also incidences of invasive herbaceous species that have also dominated the wooded grassland (Chira, 2003). Factoring that the grassland only cover less than 30% of the reserve area and the herbivore populations are increasing at high growth rate for instance, the common zebra were found to be increasing at 54% per annual in 2012 since 2005 (Ngene et al., 2012) there is need for pasture management of this habitat.

Elephant preferential utilization of woody species and its effects

Elephants in MNR were found to prefer 6 woody species as forage: *Acacia ataxacantha, A. brevispica, A. tortilis, Grewia bicolor*, *A. etbaica* and *G. tembensis*. *Acacia ataxacantha, A. brevispica,* and *A. tortilis* were more preferred than the other 3 species. A study in the reserve by Chira and Kinyamario (2009) established that elephants in MNR preferred 5 woody species in the year 2002: *Acacia ataxacantha, A. brevispica, G. villosa*, *Grewia bicolor* and *G. tembensis*. Cross-examination of these two studies shows that the elephant preference in the reserve over the 10 years shifted from *G. villosa* that was currently being avoided to *A. tortilis* and *A. etbaica,* which were the new preference. These observations are indicators of changing dynamics of preferred species structure and availability to the elephants.

Elephants foraged more on the mature plants (>3.01 m and 1.51-3.00 m height classes) of their preferred species relative to their availability. Foraging on mature woody species by elephant before fruiting may affect their regeneration (Chira & Kinyamario, 2009) this could be the possible explanation of the low availability of the seedling height class 2%. Browsing of mature *acacia drepanolobium* trees mostly by giraffes reduced their flowering thus reducing seeds production hence low seedlings recruitment in Ol Pejeta conservancy (Wahungu, Mureu, & Macharia, 2010). Continued browsing pressure and reversal of the higher height classes is detrimental since there will be less mature trees to restock the seed bank. This means less seedlings will generate. Browsing of seedlings coupled with other seedling mortality factors (Lagendijk, Mackey, Page, & Slotow, 2011) increases the risk of the species survival since less seedlings density have reduced probability of escaping the browsing trap thus reduced recruitment into higher classes.

Elephants utilize trees differently depending on their woodiness, they knock down large woody trees to access the top coppices as well as debarking them while they bite off the crowns of less woody shrubs and seedlings (Birkett, 2002). Main stem breakage and debarking by elephants was on the large woody trees as the *Acacia tortilis* and *Acacia atbaica* while selective browsing was on the shrubs species: *Acacia ataxacantha*, *Acacia brevispica, Grewia bicolor* and *Grewia tembensis*. These observations were consistent with those made by Birkett, (2002) that, elephants snap the tops of smaller trees and shrubs but push over larger trees. A typical elephant damage cycle begins with destruction of the understory, followed by ring-barking of adult trees (Laws, 1970). This reflects a significant negative impact on the *Acacia tortilis* and *Acacia etbaica*, since 61% of its population had their stem broken or crown decapitated. Elephant destruction raises concern when 50% of targeted woody plants are destroyed (Ross, Field, & Harrington, 1976). These two *Acacia species* damage level by elephants in MNR had already surpassed the 50% threshold, hence cause for alarm on the negative impacts of the high elephant density on the woody vegetation.

Twenty percent of *Acacia tortilis* and most of the *Acacia atbaica* trees along the river belt were debarked. This exposed them to successive crown-dieback and premature death due to desiccation, termite damage, fungal infections and bore beetles attack hence intensifying the elephant negative impacts (Höft & Höft, 1995). The uprooting of trees appeared to be non-specific with less than 1% recorded in the *Commiphora africana* woodland as the highest frequency. This total frequency of uprooted trees did not reach numbers to harm regeneration significantly (Höft & Höft, 1995).

Over 50% continuous preferential utilization of woody species in a confined habitat with elephant density of >1 km^{-2} exacerbates negative elephant impacts on vegetation (Höft and Höft 1995; Ross et al. 1976). This is well demonstrated by the negative correlation between the mean heights of *Acacia ataxacantha, A. brevispica,* and *A. tortilis* whose utilization was over 50% and dung density. Studies have shown that extensive browsing on previously coppiced trees suppresses their growth (Chira & Kinyamario, 2009; Lewis, 1991). The heights of these highly preferred species had been suppressed in areas where elephants preferred most. However, savanna plants have coevolved with elephants and browsing can stimulate rapid regrowth by reducing nutrients competing inter-shoots (Du Toit et al., 1990). Due to this factor, *Grewia bicolor, A. etbaica, G. tembensis* and *G. villosa* whose utilization was low <35% (2<PR>1) had their mean height still resilient and correlated positive with elephant dung density. This is a vulnerable situation of maintaining elephant browsing at equilibrium to offset the species resilience suppression. Considering *Grewia villosa* that was been preferred in 2002 but it is currently being avoided, it can be concluded that, its continued preferential utilization by elephants suppressed its mean height from 2.5 m (Chira and Kinyamario 2009) to less than 1.5 m.. *G. villosa* is a shrub species that grows up to 3 m high, but its current low average height may have led to its avoidance since 75% of trees utilized by elephants were above 1.51 m. Since it was being avoided, its height correlated positively with the dung density per transect hence, it could recuperate and become a preferred forage again if the elephant density pressure is reduced to confer recovery space and time. The effect of the elephants on target woody species in MNR could be exacerbated by the current prolonged events of droughts and incidences of bush fires in the study area (Wahungu et al. 2011). Therefore, high preference of few species where elephants aggregate in large numbers magnifies the confounding effects of elephant browsing in suppressing tree height as seen in the negative correlation between the mean heights of *A. ataxacantha, A. brevispica* and *A. tortilis* and the elephant dung density per transect.

5.3. Electric fence efficiency in control of HECs

A simple linear fence-line of 16 km with 2 solar powered strands with 5.38±0.53 kV of AC was the main design of MNR fence. Electric fencing technology is simple and definitely deters elephants in most savanna elephant ranges, or where crop raiders are determined and persistent, if it is continuously kept under good management (Hoare, 1995; C. R. Thouless & Sakwa, 1995). Constant high voltages (>5 kV) in electric fences will deter most elephants, but low voltage, a frequent manifestation of poor maintenance, may merely irritate a determined elephant, which may then destroy a section of the fence (Hoare, 2003).

A fence is only as good as its maintenance, which has to be continual and meticulous (Hoare, 2003). MNR management has a dedicated team for fence maintenance. The team charged with clearing of the perennially growing vegetation along the fence line, replacement of damaged posts by termites, and sunlight in case of plastic posts was competent enough. They also replace missing hooks for attaching the wires on the posts, maintenance of the solar panels, boosters, batteries, monitoring daily voltage, attending to any short-circuits, and replacing any missing or stolen wires along the fence. Vegetation contact causes power leakages and overgrowth conceals the fence from being an obvious barrier to elephants (Hoare, 2003) hence the need of maintaining a clear fence cutline.

A review of the fence maintenance records book revealed that there has never been an elephant fence breakage since the fence was constructed. This may mean that the fence has been good enough to deter any elephant trying to challenge it or simply the elephants avoided it. A linear fence layout like that of MNR possess the challenge of 'funneling' elephants around the open end of a fence (Hoare, 2003). The MNR occurrence book showed no recorded incidence of HEC in the fenced side of the Makima location, but varying numbers of HECs at the open ends of the fence and along the unfenced Tana and Thiba riversides. There was a significant positive relationship between the annual elephant population increase and the recorded cases of HECs along the unfenced riverside area. This means that increase in the reserve’s elephant density is increasing the HECs over time. The expectation is that a fence will effectively eliminate elephant problems; however, some ‘problem elephants’ do exist and these may need to be removed or eliminated if they can be individually identified (Hoare, 2003). From the time of fencing to January 2013, five 'problem elephants' had been eliminated to mitigate human-elephant conflicts along the Tana and Thiba rivers (Security Database, 2013). Elephants are undeterred by narrow stretches of water (Hoare, 2003), the MNR electric fence deters the elephants and funnels them to the unfenced edges of the reserve along the two rivers which they easily snorkel across into the farmlands. The fence therefore, has been effective in reducing HECs in main land of Makima location along the fence line except at the fence ends where the elephants cross the river into the neighboring farms.

The elephants invaded the residents farms before fencing of the reserve. There was a significant variation in the response on whether elephants invaded farms after the fencing. Opinions on fence effectiveness in control of HECs differed significantly. In general, 76% of the total respondents agreed that electric fence is a good mitigation measure. The elephants avoided the fence but crossed the rivers at the open ends into the farmlands hence, the reason why only farmers near the open ends of the fence reported cases of elephant conflicts unlike the ones along the fence line. HECs, in particular, the damage caused by elephants to smallholder crops, is a major challenge to the conservation of African elephant (Maximilian D. Graham, Notter, Adams, Lee, & Ochieng, 2010). Respondents from unfenced side reported 73% crop damage while their counter parts reported 33%. Crop damage, property damage and risk to human life were the main losses caused by MNR elephants to the local community. Other economic losses listed were loss of cattle, injury to people and rare cases of death, breaking of grain stores, irrigation channels and water pipelines. These sorts of losses are common in Kenya where people are killed every year by elephants in an attempt to defend their crops (Hoare, 1995; K. Kangwana, 1995; Kiiru, 1995; C. Thouless, 1994).

Residents from the two sides of MNR used similar ways of deterring elephants but in varying extends with fire and drum beating being the most common. Efforts focused on finding effective farmer-managed deterrents that are both socially and economically suitable; especially in ‘conflict’ zones where effective electric fences to separate humans from elephants are neither feasible nor affordable are essential (Omondi et al., 2004; Osborn & Parker, 2003). Majority of respondents makes noise by beating drums and shouting to scare away the elephants, lighting fire, and use of bright spotlight or burn chili to scare away the elephants and only a few (9%) report to KWS for support. Other than fencing of the reserve, the reserves’ management laxity in control of the HECs through innovative and pro-active mitigation measures was reflected in the high number of dissatisfied residents. The management did not respond rapidly to cases of elephant escape hence the reason for the very few cases of recorded HECs in the OB and the feeling by the residents that they suffer without help from the relevant authority. Many rural farmers living within elephant ranges are beyond the reach of the conventional approach used to mitigate HECs (M. D. Graham & Ochieng, 2008). For these reasons, smallholder farmers are in many cases left with the responsibility of defending their own farms from elephants (M. D. Graham & Ochieng, 2008) using traditional farm-based elephant deterrent systems (Osborn & Parker, 2003). This has a likelihood of eroding the local support since it makes them feel neglected by the management to suffer all losses and costs of conserving the elephants in the reserve.

On average, crop-raiding incidents occur within 1.54 km of areas of natural habitat where elephants can hide by day undisturbed by human activities (‘daytime elephant refuges’) (Maximilian D. Graham et al., 2010). The survey act provides that on all tidal rivers a reservation of not less than 30 metres in width above high-water mark shall be made for government purposes ("The Survey Act," 1961). Majority of the farmers who reported crop raids by elephants were those farming right adjacent to the river where the elephants take water. This to some considerable degree has increased their vulnerability to HECs due to high exposure rate to the elephants. Creation of buffer zones as a mitigation measure by cultivating buffer crops instead of maize or mangoes, which highly attract elephants is the better option. Bees and buffer crops: timber and chili are ‘eco-deterrent’, not only do they diminish loss of farming income, but also add a diverse source of income through sales of their products (King, Lawrence, Douglas-Hamilton, & Vollrath, 2009).

Other than elephants, the local community of MNR also suffers conflicts with other wildlife species significantly ($p<0.0001$). Hippos and crocodiles were the main problem animals in the unfenced riversides with 50% and 36% respectively. The electric fence was not resilient against small animals such as antelopes, warthogs, aardvarks, primates, and birds. Low specification electric fences are cheap to construct, easier to maintain, but allows smaller non-target animals to pass unhindered (M. D. Graham & Ochieng, 2008). The rivers were good natural barrier to those animals that could not withstand turbulent waters like the impalas, warthogs and primates. However, the water dwelling animals like the hippos and the crocodiles were troublemakers to the Tana and Thiba riverside communities.

Wildlife-based benefits are intended to offset costs and encourage tolerance or stewardship (Gadd, 2005). The benefits gained from the reserve differed significantly in both sides. The Makima location residents gain more benefits from the reserve than the Masinga residents. This unequal distribution of benefits may arise from the administrative boundaries differences. Tana River marks the boundary between Mbeere district to the north and Machakos district to the south (Chira, 2003). The reserve is entirely in Mbeere district while the immediate neighbors across the unfenced Tana riverside are in Machakos district. A completely inclusive and integrated approach of managing the trans-boundary resource should therefore, be applied for sustainable conservation of the reserve.

The residents expressed significantly diverse expectations towards the reserve. Both sides of the reserve highly expected the reserve management to support schools, education, and infrastructure development. However, both sides differed on their level of expectations on curbing HWCs, job opportunities, community health support and control of Tse-Tse flies. When communities living adjacent to wildlife gain tangible benefits they appreciate the linkage between benefits and active conservation thus developing ‘pro-conservation attitudes’ (Gadd, 2005). Comparing opinions from both sides: people from the fenced Makima side gain relatively more benefits from the reserve hence positive and supportive of the reserve. On the other hand, the people from the Masinga location feel alienated since the reserve is in different district and felt neglected in benefits sharing protocol, yet they are the ones who bear the greatest cost of living with the wildlife in the reserve; hence, a negative attitude and perception towards the reserve. The expectations from the Masinga residents were more of basic services to the community such as health, education, water access, control of Tse-Tse flies, and HWC while those of the Makima were more towards financial benefits and personal gains than communal benefits. If the linkage between the benefits and the health of the resource is underemphasized, beneficiaries may fail to take steps to protect the source (Infield & Namara, 2001) resulting in hostility towards the conservation area (Boonzaier, 1996). Therefore, there is a need for an integrated participatory approach in community education and awareness of the benefits that arise from the reserve and the values for biodiversity conservation. A participatory approach wins the support of the local community by making them aware of the available challenges and opportunities hence proper prioritization of the community needs and equitable distribution of available resources.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

In conclusion, the study design and the indirect index method of using elephant dung count and utilization marks satisfactorily realized the main objectives of this research as summarized herein. The elephants of MNR are cryptic and spend most of their time confined in the bushland and woodlands along the main rivers (Tana and Thiba) mainly because of food and water availability, refuge and shade. The accumulation of older elephant dung in the bushland, *Commiphora africana* woodlands and *Acacia mellifera* woodlands showed continuous utilization of these key habitats while the peripheral grasslands were avoided and rarely utilized.

Acacia ataxacantha, Acacia brevispica, Acacia tortilis, Grewia bicolor, Acacia etbaica and *Grewia tembensis* were the preferred forage woody species by elephants during this study in MNR. *Acacia ataxacantha, Acacia brevispica,* and *Acacia tortilis* were the most preferred than the other 3 species. Aggregation of high elephant densities and continuous utilization of the preferred species in the confined fenced reserve are cascading cofactors that exacerbate the confounding effects of elephant on woody species resilience.

Shift in elephant preference and diversification for woody species diet over time in the reserve were indicators of changing dynamics of elephant-vegetation interaction. The heights of *Acacia ataxacantha, Acacia brevispica,* and *Acacia tortilis,* the most preferred species had been suppressed where elephants aggregated in large numbers due to continuous selective foraging without recovery time. The suppressed height of *G. villosa* to level below the preferred elephant utilization height made it unavailable to the elephant hence, drop of its preference. This led to the shift of elephants' preference to other species like the *Acacia tortilis* and *Acacia etbaica* to fill up the gap. *Acacia tortilis, Acacia ataxacantha,* and *Acacia brevispica,* utilization level by elephants in MNR has already surpassed the 50% threshold, hence, an alarm on the negative impacts of the high elephant population density in the reserve.

It is clear that a vicious cycle of drop and pick of the preferred woody species forage is the trend as the avoided suppressed species like *G. villosa* recovers; the currently preferred ones like *Acacia tortilis, Acacia ataxacantha,* and *Acacia brevispica* become over-utilized, suppressed and consequently avoided. This is not a sustainable trend in the small isolated and confined reserve with high and growing density of 2 elephants km^{-2} since, there is no enough space to reduce continuous utilization pressure and confer good recovery time. The long-term conservation of the reserve's elephant forage woody species and their secondary ecological functions is henceforth at risk and worse even when the propensity of the impact's magnitude increases exponentially with the elephant population growth over time.

MNR has an unswerving team of fence attendants who are up to the task and have maintained the fence design and constant high voltages (>5 kV), which has been successful to deter the elephants from invading the neighboring farmlands. The residents' opinions on the performance of the electric fence were highly positive and averagely rated the fence at 76% effective in control of HECs.

The linear fence model on one side of the reserve has however, resulted to the 'funneling' effect of HECs around the open ends. The number of HECs on the unfenced sides along the Tana and Thiba rivers correlated positively with the elephant population increase over time.

External factors such as the severe drought, which occurred across Kenya in 2009 and 2010 aggravates HECs. Elephants are undeterred by narrow stretches of water; hence, the high HECs around the open ends of the fence and along the unfenced riversides.

Economic losses incurred by the MNR residents included loss of standing crops and cattle, breaking of grain stores, irrigation channels and water pipelines. Other indirect losses highlighted were lack of education for children who have to stay home to guard the crops or alter their schedules to avoid elephants and psychological stress from anticipating nocturnal raiders.

The MNR electric fence was not resilient to small animals such as impalas, warthogs, aardvarks, primates and birds. The farmers along the unfenced edges of the reserve took the responsibility of defending their own farms from elephants using traditional farm-based elephant deterrent systems.

Comparing opinions from both sides: people from the fenced Makima side gain relatively more benefits from the reserve hence positive and pro-conservation supportive attitude. On the other hand, the people from the Masinga location had negative perception, felt alienated and did not gain much benefits or support from the reserve yet they are the ones who bear the greatest cost wildlife conflicts. The expectations of the residents were high towards the reserve against the benefits they gain hence; a deterministic conclusion was not possible on a sensitive issue viewed with tension by the community.

6.2. Recommendations

To avert the identified elephant dynamic risks on the woody species, there is need of creating space and time for recovery of utilized plants. Reduction of strain to the system can be achieved by carrying out a study to determine the reserve's elephant carrying capacity.

Further, regular monitoring of the elephant-woody species density interaction dynamics is appropriate with elephant dung decay rate and density distribution and the seven woody species identified here as key indicators.

There is a need for the establishment of a proper pasture management system to avert the observed threat of grassland encroachment and invasion, for instance, the use of prescribed burning. There is a need to establish herbivore carrying capacity of the reserve emphatically, since research elsewhere has shown that habitat overutilization or underutilization can result to encroachment and invasion.

A simple modification of the electric fence like addition of chain-link below the electrified strands could screen off the passage of the antelopes, warthogs, and aardvarks hence increasing the fence effectiveness.

Scientifically based improvements of the traditional farm-based elephant deterrent systems along the riversides through the introduction and application of simple and affordable tools is necessary. Such traditional farm-based elephant deterrent systems for consideration include chili rope fences with cowbells, smoke briquettes, and noisemakers such as 'banger sticks', watchtowers with solar powered torches, and the use of African honeybees. Other tested elphant deterred methods are encircling the reserve with electric fence, digging of ditches and moats along the periphery of the rivers, creation of buffer zones and buffer crops.

Farming along the riverbank without keeping the minimum allowed 30 metres in width above high-water mark of the river should be discouraged since it is illegal and increases the probability of increased HWCs and water pollution.

In order to establish a positive perception among the residents towards the national reserve and the wildlife conservation, it is necessary to establish methods for harmonious and peaceful coexistence that supports sustainable conservation. For instance, a community program or a long-term comprehensive conflict resolution strategy based on an all-inclusive participatory approach coupled with a high level of community education and awareness creation is paramount.

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APPENDICES

Appendix I: Habitat-transect distribution and dung density table (the –sign in the Northing indicates the area was in south).

Trn	Vegetation type	Start point GPS Coordinates		End point GPS Coordinates		Dung density /ha
No		Easting	Northing	X	Y	
8	*Acacia mellifera*	37.63143	-0.82403	37.62981	-0.82463	65
9	*Acacia mellifera*	37.61710	-0.81917	37.61783	-0.81776	80
11	*Acacia mellifera*	37.63934	-0.84109	37.63927	-0.84284	115
16	*Acacia mellifera*	37.61776	-0.82260	37.61905	-0.82117	20
18	*Acacia mellifera*	37.61119	-0.82683	37.60954	-0.82675	40
22	*Acacia mellifera*	37.59481	-0.84055	37.63000	-0.82462	35
23	*Acacia mellifera*	37.59974	-0.81358	37.59995	-0.81536	130
24	*Acacia mellifera*	37.62636	-0.85290	37.62546	-0.85138	65
25	*Acacia mellifera*	37.63263	-0.79308	37.63136	-0.79424	205
26	*Acacia mellifera*	37.61880	-0.79030	37.61722	-0.78938	5
31	*Acacia mellifera*	37.64962	-0.84364	37.65138	-0.84369	170
33	*Acacia mellifera*	37.60894	-0.82211	37.60741	-0.82196	35
5	Bushland	37.63664	-0.82183	37.62488	-0.82166	25
10	Bushland	37.65303	-0.83006	37.65434	-0.83109	200
12	Bushland	37.63557	-0.83752	37.63402	-0.83694	45
19	Bushland	37.63189	-0.78924	37.63063	-0.78789	205
21	Bushland	37.65449	-0.84179	37.65574	-0.84049	160
27	Bushland	37.62562	-0.84570	37.62395	-0.84590	40
30	Bushland	37.62667	-0.83045	37.62525	-0.82899	50
40	Bushland	37.64458	-0.82229	37.64534	-0.82343	240
3	*C. africana*	37.61046	-0.84358	37.61113	-0.84228	60
7	*C. africana*	37.60088	-0.85079	37.60016	-0.84916	60
14	*C. africana*	37.60945	-0.85450	37.60807	-0.85443	110
20	*C. africana*	37.61498	-0.84766	37.61423	-0.84607	10
29	*C. africana*	37.60508	-0.83557	37.60338	-0.83509	15
32	*C. africana*	37.59254	-0.83599	37.59252	-0.83562	95
34	*C. africana*	37.62524	-0.82906	37.62592	-0.83068	30
35	*C. africana*	37.62521	-0.80546	37.62662	-0.80630	50
36	*C. africana*	37.62367	-0.82527	37.62298	-0.82449	70
39	*C. africana*	37.62500	-0.82596	37.62561	-0.82750	80
1	W. Grassland	37.59184	-0.82461	37.59284	-0.82304	0
2	W. Grassland	37.60119	-0.79647	37.60294	-0.79607	0

3	W. Grassland	37.59123	-0.82893	37.59302	-0.82947	0
4	W. Grassland	37.60994	-0.79765	37.60878	-0.79933	0
6	W. Grassland	37.60804	-0.79581	37.60842	-0.79406	5
13	W. Grassland	37.59356	-0.80442	37.59370	-0.80264	0
15	W. Grassland	37.60165	-0.79252	37.59992	-0.79197	0
17	W. Grassland	37.59564	-0.80741	37.59568	-0.80560	15
28	W. Grassland	37.60937	-0.78981	37.60767	-0.78960	0
38	W. Grassland	37.59296	-0.80778	37.59119	-0.80756	10

Appendix II: Woody species/ha distribution in each vegetation type

No.	***Acacia mellifera* woodland Species**	Freq.	Plants/ha	Relative Freq.%
1	*Grewia bicolor*	281	293	20
2	*Acacia mellifera*	263	274	19
3	*Grewia tembensis*	248	258	18
4	*Grewia villosa*	184	192	13
5	*Acacia ataxacantha*	126	131	9
6	*Grewia truncata*	94	98	7
7	*Commiphora africana*	62	65	4
8	*Acacia brevispica*	51	53	4
9	*Acacia etbaica*	32	33	2
10	*Combretum exalatum*	21	22	1
11	*Acacia tortilis*	13	14	1
12	*Maytenus putterickioides*	12	13	1

No.	Wooded Grassland Species	Freq.	Plants/ha	R. Freq. %
1	*Ormocarpum kirkii*	165	206	31
2	*Combretum aculeatum*	106	133	20
3	*Acacia hockii*	102	128	19
4	*Commiphora africana*	97	121	18
5	*Maytenus putterickioides*	53	66	10
6	*Combretum molle*	34	43	6
7	*Rhus natelensis*	31	39	6
8	*Grewia bicolor*	12	15	2
9	*Acacia nilotica*	9	11	2
10	*Terminalia brownii*	7	9	1
11	*Sideroxylon inerme*	7	9	1
12	*Grewia truncata*	5	6	1
No.	**Bushland Species**	**Freq.**	**Plants/ha**	**R. Freq. %**
1	*Grewia bicolor*	199	311	20
2	*Acacia ataxacantha*	137	214	14
3	*Grewia tembensis*	125	195	12
4	*Grewia villosa*	89	139	9
5	*Acacia mellifera*	88	138	9
6	*Commiphora africana*	87	136	9
7	*Grewia truncata*	80	125	8

8	*Acacia brevispica*	76	119	8
9	*Lantana camara*	49	77	5
10	*Acacia etbaica*	19	30	2
11	*Acacia tortilis*	12	19	1
12	*Ozoroa insignis*	11	17	1
No.	**Commiphora africana Woodland Species**	**Freq.**	**Plants/ha**	**Freq. %**
1	*Commiphora africana*	263	329	27
2	*Grewia villosa*	178	223	18
3	*Acacia mellifera*	176	220	18
4	*Grewia tembensis*	169	211	17
5	*Grewia bicolor*	129	161	13
6	*Grewia truncata*	83	104	9
7	*Acacia ataxacantha*	69	86	7
8	*Acacia etbaica*	42	53	4
9	*Acacia brevispica*	22	28	2
10	*Maytenus putterickioides*	18	23	2
11	*Ozoroa insignis*	16	20	2
12	*Acacia senegal*	15	19	2

Appendix III: Table of all identified woody species preference ratio

	Utilization Status					
Species	Yes	No	Total	Utilization (U) %	Availability (A) %	PR= U/A
Grewia bicolor	203	418	621	18	14.44	1.22
Grewia tembensis	152	392	544	13	12.65	1.05
Acacia mellifera	128	399	527	11	12.25	0.91
Commiphora africana	84	425	509	7	11.83	0.62
Grewia villosa	92	363	455	8	10.58	0.76
Acacia ataxacantha	181	151	332	16	7.72	2.04
Grewia truncata	32	230	262	3	6.09	0.46
Ormocarpum kirkii	42	150	192	4	4.46	0.82
Acacia brevispica	78	71	149	7	3.46	1.96
Acacia hockii	30	88	118	3	2.74	0.95
Combretum aculeatum	21	88	109	2	2.53	0.72
Acacia etbaica	31	65	96	3	2.23	1.21
Maytenus putterickioides	11	74	85	1	1.98	0.48
Lantana camara	7	44	51	1	1.19	0.51
Rhus natelensis	8	32	40	1	0.93	0.75
Combretum molle	4	35	39	0	0.91	0.38
Ozoroa insignis	1	35	36	0	0.84	0.10
Acacia tortilis	19	15	34	2	0.79	2.09

Acacia senegal	6	18	24	1	0.56	0.94
Combretum exalatum	2	19	21	0	0.49	0.36
Lonchocarpus bussei	7	10	17	1	0.40	1.54
Acacia nilotica	1	10	11	0	0.26	0.34
Terminalia brownii	5	3	8	0	0.19	2.34
Sideroxylon inerme	2	5	7	0	0.16	1.07
Scutia myrtina	1	3	4	0	0.09	0.94
Acacia condyloclada	0	3	3	0	0.07	0.00
Acacia tirion	0	3	3	0	0.07	0.00
Euclea divinorium	0	1	1	0	0.02	0.00
Lannea sp	0	1	1	0	0.02	0.00
Sclerocarya birrea	0	1	1	0	0.02	0.00
Monanthotaxis fonicata	0	1	1	0	0.02	0.00
Total	**1148**	**3153**	**4301**	**100**	**100**	**1**

Appendix IV: Elephant dung count data sheet

Transect No_____ Habitat___________ Transect Length_____ m Date: ___/__/_____

GPS: Starting Point_________/__________End Point_______/_______ Bearing____ ^{0}

Dung Pile No.	Dist. frm strt pt (m)	GPS Coordinates		Xi (Perp. Dist.) (m)	Decay Category	Comments
		Northings	Easting			

Appendix V: Elephant dung decay rates datasheet

Dung Pile No.	Habitat	GPS Coordinates		Category	Date/ # of days	Category	Date/ #of dys	Category	Date/ #of dys	Category	Date/ #of dys	Category	Date/ #of dys
		Northings	Easting										

Appendix VI: Elephant- habitat interaction datasheet

Transect No_____ Habitat___________ Transect Length_____ m Date: ___/__/_____

GPS: Starting Point_________/__________End Point_______/_______ Bearing____^{0}

Tree No.	Species	Height (m)	Diameter (mm)	DMG Status	DMG Height	DMG Type	Damager	Comments

Appendix VII: Structured questionnaire

Survey of the Opinions of Residents around Mwea National Reserve on the effectiveness of Electric Fence in Control of Human Elephant Conflicts

University of Eldoret

School of Environmental Studies

P.O. Box 1125- 30100, Eldoret

The information provided in this questionnaire will be held confidential and used purely for academic purpose in the partial fulfillment for the requirements of Master's degree in Environmental Biology and make recommendations to the management of Mwea National Reserve based on your insight.

Kindly spare some of your precious time and support me in realizing the objectives of this research by completing the following questions.

March 2013

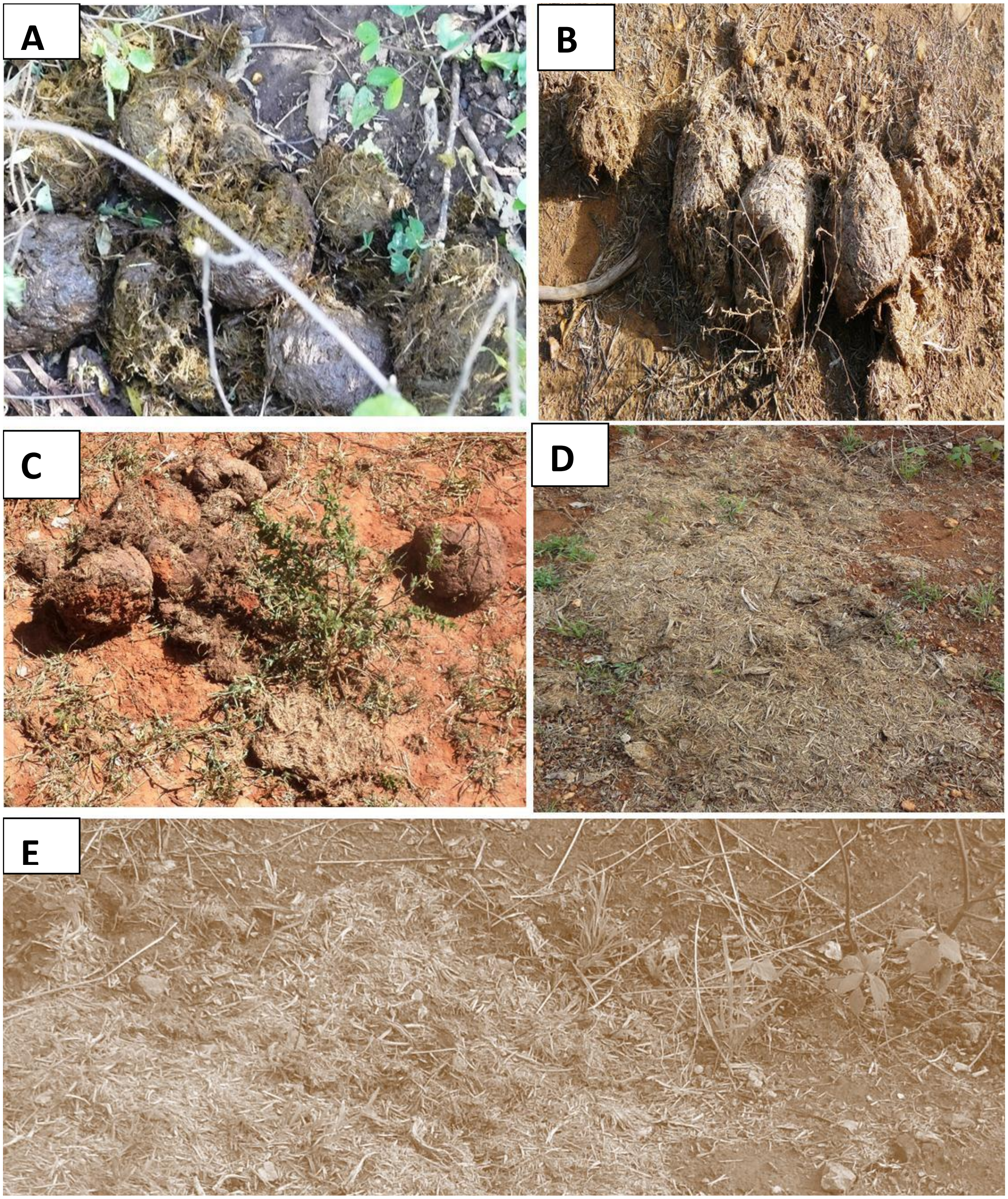
To be field by a Makima village resident

Please Tick where appropriate.

1. Sex: Male ☐ Female ☐ Village _______________
2. How long have you lived in this village? Less than 10 yrs. ☐ Over 10 yrs. ☐
3. Have you ever visited the Mwea National Reserve? Yes ☐ No ☐
4. Did you live here before the Reserve was fenced? Yes ☐ No ☐
5. Did the Elephants used to come to your farm before the fence was build? Yes ☐ No ☐
6. If yes, what did they used to do? Damage Crops ☐ Destroy property ☐ Injure people Others ☐ (please specify) ____
7. Do the Elephants escape out of the reserve into your farm? Yes ☐ No ☐
8. If yes, what season of the year do they escape most? Dry Wet ☐ and at what time? ☐ Day ☐ Night ☐ How do they escape from the reserve? Break the fence Cross the river ☐ Others (specify)__________________What do you do to prevent the elephants from breaking into your farm? Make Noise Use fire ☐ Call KWS for assistance ☐ Others (specify) _________
9. What losses do you suffer from Elephants when they break into your farm: Body Injury Cause Death to livestock ☐ People ☐ Threat to live ☐ crop damage ☐ property damage ☐ lack of sleep ☐ others (specify)___________
10. What other animals from the reserve cause conflicts to the community: ____
11. What do KWS and the Mbeere C.C. do to minimize the losses incurred? ____
12. In your own opinion, do you think that the construction of the electric fence is beneficial to the community? Yes ☐ No ☐
13. What benefits do the Makima people get from the Reserve____
14. What would you like to be done so that the people of Makima Village can benefit more from the reserve? ____

Appendix VIII: Elephant dung decay categories

Photos taken during data collection (source: Author, 2013)



Appendix IX: Elephant utilization mode of woody species

Photos taken during data collection (source: Author, 2013)